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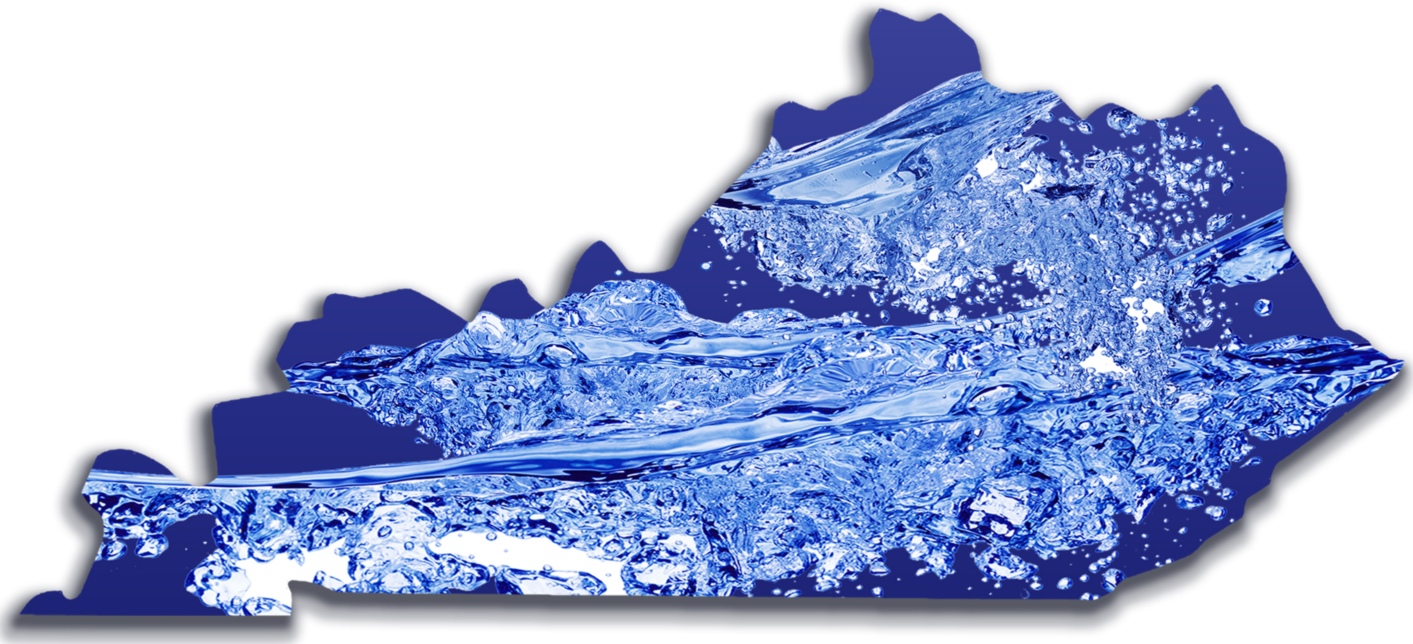
2021 Kentucky Water Resources Annual Symposium



September 13, 2021

Marriott Griffin Gate Resort | Lexington, KY

Kentucky Water Resources Research Institute

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Agenda

2021 Kentucky Water Resources Annual Symposium

September 13, 2021
Marriott Griffin Gate Resort, Lexington, Kentucky

Registration and Continental Breakfast (8:00 a.m. - 8:30 a.m.)

PLENARY SESSION (8:30 a.m. - 9:45 a.m.)
Location: Salons E-H

8:30 *Welcome & Introductions*, Steve Evans, Assistant Director, Kentucky Water Resources Research Institute.

8:35 *Overview of the Institute*, Lindell Ormsbee, Director, Kentucky Water Resources Research Institute.

8:45 *Overview of the Kentucky Division of Water*, Carey Johnson, Director, Kentucky Division of Water.

9:05 *Can You Hear Me Now?*, Dale Threatt-Taylor, Executive Director, The Nature Conservancy, South Carolina Chapter.

9:25 Panel Discussion and Q & A.

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SESSION 1 (10:00 a.m. - 11:20 a.m.)
Location: Salons E-H

Water Research: Impacting the Lives of Kentuckians
Moderators: Steve Evans (KWRRI) & Malissa McAlister (KWRRI)

10:00 *Investigation and Remediation of an Urban Karst Groundwater Gasoline Leak at Lost River Cave, Bowling Green, Kentucky*, Jason Polk, Director of the Center for Human GeoEnvironmental Studies (CHNGES) and HydroAnalytical Lab, WKU.

10:20 *Spatial and Seasonal Variation in Concentrations of Disinfection Byproducts in the Public Drinking Water System of Martin County, Kentucky*, Jason Unrine, Professor, Department of Plant and Soil Sciences, UK.

10:40 *Farmer to Farmer: Virtual Shop Talks*, Amanda Gumbert, Extension Water Quality Specialist, College of Agriculture, Food & Environment, UK.

11:00 **Solutions Begin With Understanding: Off-the-Grid Communities and Contaminated Karst Groundwater in Southcentral Kentucky*, Chris Groves, Director, Crawford Hydrology Lab, WKU.

POSTER SESSION (11:20 a.m. - 12:15 p.m.)
Location: Dixiana & Lands End and Calumet & Darby Dan

AWARDS LUNCHEON (12:15 p.m. - 1:30 p.m.)
Location: Salons A-D

Break (1:30 p.m. - 1:40 p.m.)

SESSION 2 (1:40 p.m. - 3:20 p.m.) Location: 2A - Salons E-H, 2B - Salons A-D		
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1:40	*Update to the 2019 Nutrient Loads and Yields in Kentucky Study,* Caroline Chan, GIS & Data Analysis Section, Watershed Management Branch, Kentucky Division of Water.	**In Situ 3D Electrical Resistivity Method for Understanding Water Dynamics in Shallow Karst Features*, Junfeng Zhu, Kentucky Geological Survey, UK.
2:00	*Lexmark Rainwater Harvesting System – Turning Unused Infrastructure and Problematic Stormwater into an Award-Winning Asset,* John Magner and Sam Lee, Stantec.	**Identifying the Intersection of Contaminated Karst Water and Off-the-Grid Communities in Southcentral Kentucky Using GIS*, Amy Hourigan, Dept. of Earth, Environmental, and Atmospheric Sciences, WKU.
2:20	*Leveraging Intersections: Integrating Watershed Management and Hazard Mitigation Planning to Combat Climate Change*, Mahtaab Bagherzadeh, Kentucky Division of Water.	*Groundwater Characterization: How Much Data is Enough?* Benjamin Tobin, Kentucky Geological Survey, UK.
2:40	*Riparian Reforestation for Stream-water Quality Improvement: Evidence from Reforested Urban Sites in Lexington*, Kenton Sena, Lewis Honors College, UK.	**Examining Hydrogeological Dynamics of Baselevel and Reverse Flow of the Green River and Major Springs of Mammoth Cave, Kentucky*, Matthew Cecil, Center for Human GeoEnvironmental Studies, WKU.
3:00	*Red River Gorge, Kentucky Non-Point Source Pollution Program Implementation*, Mac Cherry, U.S. Forest Service.	*Soil Moisture Micronet in the Daniel Boone National Forest*, Charles O'Connell, Kentucky Mesonet, WKU.

Break (3:20 p.m. - 3:30 p.m.)

SESSION 3 (3:30 p.m. - 4:30 p.m.) Location: 3A - Salons E-H, 3B - Salons A-D		
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3:30	*Salinization and Alkalinization of Kentucky Lake: A Result of Human Activity?* David White, Hancock Biological Station, Murray State Univ.	**Starter Fertilizer Impacts on Turfgrass Establishment and Quality*, Brad Lee, Dept. of Plant and Soil Sciences, UK.
3:50	*Tools for Wetlands Assessment and Prioritization: Assets in Abating Nonpoint Source Pollution*, Michaela Lambert, Nonpoint Source & Basin Team Section, Kentucky Division of Water.	*Blue Water Farms: Edge-of-Field Monitoring of Nutrient and Sediment Loss from No-Till Corn and Soybean Fields in the Lower Green River Watershed*, Mark Akland, Dept. of Plant and Soil Sciences, UK.
4:10	*Monitoring McConnell Springs Stormwater Quality Wetland Pond and Gainesway Pond Retrofit: 2010-2021*, David Price, Division of Water Quality, Town Branch Laboratory, Lexington-Fayette Urban County Government.	*Blue Water Farms: Edge-of-Field Monitoring of Nutrient and Sediment Loss from Wetland Watersheds in the Northern Mississippi Embayment*, Leighia Eggett, Dept. of Plant and Soil Sciences, UK.

Adjourn (4:30 p.m.)

* Denotes project supported by USGS 104b grant funds.

Poster Session (11:20 a.m. - 12:15 p.m.)

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2. *Developing ANN Model for Predicting Lake Michigan E. Coli Counts*, Chandra Chandramouli, Construction Science and Organizational Leadership Department, College of Technology, Purdue University Northwest.
3. *Examining Long Term Trends in Rainfall and Stream Flow at Upper Wabash River Basin Using Self Organizing Map*, Chandra Chandramouli, Construction Science and Organizational Leadership Department, College of Technology, Purdue University Northwest.
4. *Investigating Water and Sediment Transport Processes with High-Resolution Sensor Measurements and Hysteresis Analysis in the Cane Run Royal Spring Basin, Kentucky, USA*, Leonie Bettel, Dept. of Civil Engineering, UK.
5. *Blue Water Farms: Edge-of-Field Water Quality Monitoring of Nutrient and Sediment Loss from No-Till Corn and Soybean Fields in the Lower Cumberland River Watershed*, Sarah Cain, Dept. of Plant and Soil Sciences, UK.
6. **Determination of Microcystin Cyanobacterial Toxins in Kentucky Lakes by Diffusive Gradients in Thin Films*, Catherine Esparza, UK Sustainable Agriculture Program, and Irena Antic, Dept. of Biology, UK.
7. *Environmental Conditions on the Lower Ohio River with Comments on Phytoplankton Assemblages*, Susan Hendricks, Hancock Biological Station, Murray State University.
8. *Restoring Kentucky Streams Containing the Threatened Arrow Darter*, Cat Hoy and Rebecca Buchanan, Beaver Creek Hydrology.
9. *Comparisons of Conductivity and Chloride Concentrations in the Upper Ohio River Valley During Summer and Winter Months*, Emily Huff, Dept. of Biological Sciences, West Liberty University.
10. *Development and Optimization of Green Polymer and Solvent-Based Ultrafiltration Membranes for Water Treatment Applications*, David Lu, Dept. of Chemical and Materials Engineering, UK.
11. *Municipal Water Quality Concerns and Rebuilding Trust in a Rural Community*, Anna Hoover, College of Public Health, UK.
12. *Application of a Water Treatment Inspired Technique on a 3D Support for Air Filtration*, Ebuka Ogbuoji, Dept. of Chemical and Materials Engineering, UK.
13. *Comparison of Leaf Litter Bag and Environmental DNA in Detection of Salamanders in Maywoods Environmental and Educational Laboratory*, Rebecca Piche, Dept. of Science and Health, Asbury University.
14. *Reusable Polymeric Sorbents and their Applications in Water Remediation*, Molly Frazar, Dept. of Chemical and Materials Engineering and UK Superfund Research Center.
15. *Investigating Plant-Soil Processes and Nitrate Seasonality Using High Resolution Sensors and Stable Isotope Measurements*, Brenden Riddle, Dept. of Civil Engineering, UK.
16. *Development and Validation of qPCR Assays for Use in eDNA Detection of Ambystoma Species*, Elizabeth Strasko, Dept. of Science and Health, Asbury University.
17. *Is Chloride Driving Specific Conductance in Streams in the Upper Ohio River Valley?* James Wood, Dept. of Biology, West Liberty University.
18. **The Use of Electrical Resistivity Tomography for Delineating Ridgetop Wetland Hydrogeology in the Daniel Boone National Forest in Eastern Kentucky*, B. Marley Yopp, Dept. of Geosciences, EKU.

* Denotes project supported by USGS 104b grant funds.

The 2021 Kentucky Water Resources Annual Symposium was made possible with support from:

Plenary Session

Carey Johnson, Director, Kentucky Division of Water

Carey Johnson is Director of the Division of Water within the Kentucky Energy and Environment Cabinet. Originally hailing from Boone County in northern Kentucky, he received a BS and MS in Soil Science from the University of Kentucky College of Agriculture. For the past 19 years, he has led activities to help the Division accomplish goals in natural hazards management and resilience, developing and utilizing digital tools, and Clean Water and Safe Drinking Water Act activities. Carey oversees the Cooperating Technical Partners (CTP) program with FEMA to identify flood hazards and reduce flood risks across the Commonwealth. He also serves as the state lead for Kentucky Silver Jackets collaborative efforts with the US Army Corps of Engineers. Carey is a current member of the Technical Mapping Advisory Council (TMAC), a federal advisory committee established to review and make recommendations to FEMA on matters related to the national flood mapping program. He represents the Division on the National Dam Safety Review Board (NDSRB), as an Ohio River Sanitation Commission (ORSANCO) Commissioner proxy, and the Kentucky Agriculture Water Quality Authority. He currently serves as a steering committee member of the Ohio River Basin Alliance (ORBA) and on the Kentucky State Hazard Mitigation Council. In June 2020, Carey was elected chairperson of the Association of State Floodplain Managers (ASFPM) – a scientific and educational nonprofit organization with over 7,000 members dedicated to reducing flood losses across the nation.

Dale Threatt-Taylor, Exec. Director, The Nature Conservancy SC Chapter

Dale Threatt-Taylor is the Executive Director of The Nature Conservancy South Carolina Chapter (TNC SC). She received a Bachelor of Science in Conservation from North Carolina State University and a Master of Environmental Management from Duke University in 2011. In 2012, she was selected as one of 30 agriculturalists in North Carolina identified to participate in the Agricultural Leadership Development Program at North Carolina State University.

Her career began as a Soil Conservationist with the USDA Natural Resources Conservation Service and she later joined the Wake Soil and Water Conservation District (SWCD). In 2008, she was selected as District Director of Wake SWCD and Wake County Soil and Water Conservation Department. Her role as Executive Director for

TNC SC has provided the opportunity to build new relationships between natural resource conservationists and environmentalists across the nation.

Dale's conservation and environmental leadership includes service on many national, state, and local boards and committees. On August 1, 2020, Dale made history when elected to serve as Chair of the Soil and Water Conservation Society's national Board of Directors. She also serves on TNC's North American Agriculture Committee and on the Executive Board of Sustain SC.

On April 22, 2021, Dale was invited to join the Board of Visitors of the Nicholas School of the Environment at Duke University.

Having received many awards throughout her career, one caught her by surprise, The Order of the Long Leaf Pine from North Carolina Governor Roy Cooper for her dedicated work in conservation. Dale wants everyone to understand that locally led conservation begins with an individual, and together, our conservation work is so important in protecting the lands and waters on which all life depends.

Session 1: Water Research: Impacting the Lives of Kentuckians

Investigation and Remediation of an Urban Karst Groundwater Gasoline Leak at Lost River Cave, Bowling Green, Kentucky

Jason S. Polk[1], James Shelley[1], Kevin Strohmeier[2], Matt Powell[3], James Troxell[1], Britton Davis[1], and Nenad Maric[4]
[1]Center for Human GeoEnvironmental Studies, Western Kentucky University
[2]Kentucky Department of Environmental Protection, Division of Waste Management
[3]Environmental Compliance Division, Department of Public Works
[4]Department of Ecological Engineering, University of Belgrade
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Since the 1980's, the City of Bowling Green, Kentucky, has dealt with numerous gasoline leaks in the underground rivers that comprise its urban karst landscape. After extensive work to conduct dye traces, geophysical investigations, and mapping of the cave passages and groundwater system, many of the issues derived from leaking underground storage tanks (USTs) and other surface spills were eradicated as sources were identified and regulations and UST installation and monitoring practices evolved to reduce the threat of leakage. Recently, in March 2019 gasoline fumes were detected within Lost River Cave at the tourist entrance and throughout other parts of the system at actionable concentrations that persisted for several weeks on and off. Following storm event activity, the fume concentrations increased and persisted at levels that initiated a response by the Kentucky Division of Waste, EPA, City of Bowling Green Environmental Compliance Division, and WKU CHNGES to locate and resolve the source of the leak as it had spread throughout the underground passages of Lost River and was affecting cave tours and several residences within the area. After an initial investigation of the area for obvious leaks or sources from local gas stations and bulk facilities, additional work was conducted to locate sinkholes, fumes, and other potential sources. A sinkhole was opened after finding high concentrations of fumes using a PID, which led to the discovery of an extensive epikarst cave system with a running stream in which product was discovered and sampled. Analysis indicated weathered gasoline and a dye trace study was conducted using three dyes from a nearby bulk facility with aged storage tanks and to connect the newly discovered stream to Lost River and surface water bodies, from which all traces were successful. After identifying the potential source being the bulk plant, UST removal occurred and additional monitoring of downstream sample sites was undertaken to measure the reduction of the gasoline as the system responded to storm events and the remediation process. Upon removal of the tanks and after multiple storm flushes, the fumes decreased and the detection of gasoline in the new cave fell below actionable levels. Longer-term study of the site is underway to analyze the natural hydrocarbon attenuation through karst hydrologic and microbiological processes in the system. Additional dye tracing was conducted to determine the drainage area of the contaminated cave to continue to interpret the event for future mitigation. The project led to the discovery of a new tributary to the system and the need for improved mapping, GIS database construction, dye tracing, facility monitoring, and emergency response planning for urban karst groundwater contamination events, which are currently underway for the City of Bowling Green and being developed for application across urban karst areas.

Spatial and Seasonal Variation in Concentrations of Disinfection Byproducts in the Public Drinking Water System of Martin County, Kentucky

Jason M. Unrine[1], Nina McCoy[1,2], W. Jay Christian[3], Wayne Sanderson[4], Ricki Draper[1,2,5], Madison Mooney[1,2], Lindell Ormsbee[6,7], Mary Cromer[8], and Anna G. Hoover[9]
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[2]Martin County Concerned Citizens, Inc.
[3]Department of Epidemiology, University of Kentucky
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Drinking water disinfection byproducts (DBPs) are formed when disinfectants (e.g. chlorine, bromine, chloramine, UV radiation, ozone) react with natural and anthropogenic organic matter and inorganic ions during treatment of drinking water. Of the myriad compounds that are formed, two classes of organic compounds trihalomethanes (THMs) and haloacetic acids (HAAs), as well as the inorganic ions bromate and chlorite, are currently regulated under the Safe Drinking Water Act based on their prevalence and toxicity. These compounds have been associated with a range of adverse health effects depending on exposure level and duration. Controlling levels of DBPs can be challenging for drinking water systems with degraded infrastructure and inadequate financial and technical resources, particularly those that rely on chlorination as a disinfection method and surface water as the source water. The drinking water system in Martin County, Kentucky has a history of violations of DBP regulations, and can serve as a case study for investigating the formation of DBPs in rural drinking water systems.

To increase our understanding of the factors that influence formation of DBPs in Martin County and within rural drinking water systems in general, we investigated the spatial and seasonal variation in THM and HAA concentrations in relation to drinking water properties (pH, temperature, conductivity, total chlorine, free chlorine, total organic carbon, network distance from the treatment plant). We collected drinking water samples from 97 individual homes over the course of one year and analyzed them for temperature, electrical conductivity, pH, free chlorine, total chlorine, THMs (chloroform, bromodichloromethane, dibromochloromethane, dichlorobromomethane, and bromoform) and HAAs (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, bromoacetic acid, and dibromoacetic acid).

Spatial correlation analysis revealed no spatial clustering for THM concentrations and only weak clustering for HAA concentrations. In contrast, there was a strong seasonal pattern for both HAA and THMs, with concentrations of HAA peaking in mid-summer and THMs peaking in early fall. Multiple regression analysis revealed that THM concentrations were most strongly related to conductivity, while HAA concentrations were more strongly related to temperature. Further regression analysis of the data for individual compounds revealed that DBP compounds that only contained chlorine halogen groups were strongly associated with temperature, while compounds containing bromine were more strongly correlated with conductivity. While we did not collect source water for this experiment, we suspect that these patterns could be explained by the concentrations of pre-cursors in source water and how they relate to these properties. Future studies should incorporate sampling of source water to better understand DBP formation factors. A more detailed spatial analysis that that takes into account the locations of storage tanks and other features of the distribution network also may be necessary. Finally, DBPs are regulated on a running annual average basis; however, temporary exceedances of the MCLs during summer and fall were driven by increases in formation of brominated DBP compounds during periods of increased electrical conductivity. Brominated DBPs tend to have higher toxicity than DBPs containing only chlorine. The sources of bromine in source water therefore should be investigated. Previous research has indicated that coal mining and coal combustion waste are potential sources of bromine, but natural geogenic sources also are possible.

Farmer to Farmer: Virtual Shop Talks

Amanda Gumbert[1], Beth Baker[2], Rebecca Power[3], Mike Daniels[4], Jenny Seifert[3], Erica Gentry[5], Andrew Lucore[2], Amber Radatz[5], Anne Nardi[3], Samuel Pratsch[6], Brittany Isidore[6], and Amber Mase[6]
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[2]College of Forest Resources, Mississippi State University
[3]North Central Region Water Network, University of Wisconsin-Madison
[4]Crop, Soil & Environmental Science, University of Arkansas
[5]Wisconsin Discovery Farms, University of Wisconsin-Madison
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A significant portion of the Mississippi-Atchafalaya River basin is farmland, and farmers across this landscape have the potential to impact water quality by utilizing conservation practices and sharing their successes and challenges with their peers. Building on the foundation of an in-person farmer leadership exchange held in 2020, land-grant partners in the Mississippi-Atchafalaya River basin pivoted due to the pandemic to offer a series of virtual farmer exchanges in winter 2021. These events were part of an EPA-supported, multi-state project to facilitate peer learning among farmers about conservation. The University of Kentucky Cooperative Extension Service led the planning of this event, which brought together farmers and natural resources managers from across the Mississippi-Atchafalaya River basin, including several from Kentucky.

The Virtual Farmer Shop Talk series was offered as four stand-alone events on a Zoom platform. Topics included conservation finance, nutrient management planning, on-farm trials, and farmer successes with conservation practices. Each event featured a panel of expert and farmer speakers followed by facilitated discussion among attendees. The final event featured an all-farmer panel (including a Kentucky farmer) with panelists sharing their experiences with conservation practices. The series attracted nearly 200 participants from 18 unique states, with each session recorded and made available online for later viewing. Farmers represented row crop, large and small livestock, and fresh market produce operations.

Post-workshop evaluations indicated that 89% of respondents learned about practices that would save money are their farms; 78% learned about a resource to help them implement conservation practices; and 89% gained confidence in their ability to effectively implement conservation practices.

Successes of the series include expanding the technological capacity of the implementation team for virtual events, building of social capital among the team members, broadening the geographical reach of the project, and facilitating meaningful conversations for peer-to-peer learning. Several farmers commented on how refreshing it was to learn from other farmers even when production practices were varied by geography and commodity.

The project team learned several valuable lessons from these virtual farmer exchanges: 1) farmers need a network of peers to support them in the implementation of conservation practices; 2) high-quality, content-rich conversations among a few farmers are far more important than the overall number of participants; 3) farmers are open to virtual learning when it provides opportunities for meaningful information exchange; and 4) virtual platforms are a valuable tool for conservation practice peer-to-peer learning.

Peer-to-peer learning is an effective and preferred way for farmers to learn new practices. In addition to this event, the project is facilitating farmer-to-farmer learning through a mini-grant program to establish or expand demonstration sites and an online platform for farmers to connect digitally.

Solutions Begin with Understanding: Off-the-Grid Communities and Contaminated Karst Groundwater in Southcentral Kentucky*

Chris Groves[1], Lee Anne Bledsoe[1], Pat Kambesis[1], Amy Hourigan[1], Margaret Gripshover[1], Marissa Schorr[2], and Susan Jones[3]
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[2]Geoscientist in the Parks Program, National Park Service
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In a unique geographic concordance, there are many Amish and Mennonite communities living on southcentral Kentucky's Pennyroyal Plateau. As in other karst landscapes there is limited availability of surface water, and groundwater is generally contaminated by agricultural land use. Many families here are choosing to live off-the-grid and forgoing certain modern technologies, in some communities even living without electricity. A question presents itself: in very rural areas of the karst landscape here where little or no water is available at the surface, and groundwater is likely to be contaminated, where are families without electricity getting water, how are they moving it around, and how are they making it safe to drink?

The answers are complex, and we report here on recent progress by scientists and students in Western Kentucky University's Crawford Hydrology Lab and our colleagues to develop relationships that are the first step to understand the physical and cultural complexities of these communities and their interactions with water. In the first phase of this work, we showed that over a one-year effort every sample of untreated water from four family karst water supply springs in Barren and Monroe Counties was contaminated with fecal bacteria, and that relatively simple home treatment with reverse osmosis—in communities where electricity is available—provides effective treatment even during storms when contaminant levels rise.

The biggest potential challenges appear to be in communities in which there is no electricity. In places people are hand-carrying water from karst springs and drinking it without treatment, and in some cases, people are getting ill as a result.

We are developing a Geographic Information Systems (GIS) database to quantify the concordance of karst hydrogeology and such off-the-grid communities in the ten-county Barren River Area Development District of southcentral Kentucky and have published an ArcGIS Story Map *Hidden Landscapes: Potentially Vulnerable Communities in Kentucky's Karst Groundwater Region.* In early 2021, in a participatory project we conducted a workshop *Groundwater Safety in Limestone Country* for Allen County's Old-Order Mennonite Red Hill Community.

In fieldwork to gather data for these efforts we are developing relationships and learning a great deal about this fascinating physical/cultural landscape. There is a range of methods used to move water without electricity. One common device uses horses (or other animals) on treadmills (Figure 1) which can power water pumps and run a variety of other tasks, and other engineering designs convert forms of mechanical energy in water (in a clever application of Bernoulli's law) to lift water without external power sources (Figure 2).

**This presentation is based upon work supported by the U.S. Geological Survey under Grant/Cooperative Agreement No. G20AS00025, WRRI 104B Annual Grant Program.*

Figure 1. In Kentucky Mennonite communities without electricity, animal-powered treadmills are used to pump water and can provide power for a variety of other tasks. These horses on this day were driving a cement mixer (photo by Chris Groves).

Figure 2. Exploiting a clever application of Bernoulli's Law, this Allen County device lifts water to operate a grinding mill with no external power sources (photo by Chris Groves).

Session 2A: Watershed Management I

Update to the 2019 Nutrient Loads and Yields in Kentucky Study

Caroline Chan and Josiah Frey
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The 2019 report, *Nutrient Loads and Yields in Kentucky: 2005-2017* looked at statewide long-term monitoring of nutrients to determine the extent of nutrient pollution in Kentucky's waters, where the problem is greatest, and how the levels of nutrient pollution have been changing. The information in this study was helpful in determining where to focus nutrient reduction efforts. The study also made clear that long-term data assessment is important to understand what actions are effective, and whether other factors should be considered.

In June 2021, the Division of Water (DOW) released the report, *Update to the 2019 Nutrient Loads and Yields in Kentucky Study*. This update builds on the prior study, adding two years of data (2018, 2019). Beyond the 57 monitoring stations from the earlier study, five monitoring locations at the mouths of major tributaries to the Ohio River were added. These locations, monitored by the Ohio River Valley Water Sanitation Commission (ORSANCO), are useful for showing larger trends as well as helping to answer the question: What is Kentucky's total contribution of nutrient pollution to the Mississippi River Basin?

As with the earlier study, higher nutrient pollution was found in areas of the state with greater amounts of agriculture. However, the additional years had greater variability in loads and yields than the previous time period, especially for nitrogen, indicating some kind of change. A look at precipitation across the study time period showed that, along with 2011, the two added years, 2018 and 2019, had unusually high precipitation totals. Rain events could have resulted in greater nutrient runoff than in years with more typical rainfall.

This study also estimated the total amount of nutrients coming from Kentucky. The combination of DOW's and ORSANCO's monitoring stations accounted for 82% of Kentucky's drainage area. The remaining 18% of land area was estimated by looking at the relationship between land use and nitrogen and phosphorus yields. This estimate indicated that about 105,000 tons/year of nitrogen and 12,000 tons/year of phosphorus left Kentucky annually for the Mississippi River Basin.

As DOW examines problems caused by excess nutrients in Kentucky waters, we will continue to investigate the relationship between high precipitation totals and increased loads– perhaps as a result of climate change – and whether 2018 and 2019 were unusual years. The Division will also work to fill in the spatial gaps to more accurately determine Kentucky's average nutrient load. DOW will continue to assess nutrient data to understand if our strategies are effective, and identify other factors affecting nutrient loss.

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Lexmark Rainwater Harvesting System – Turning Unused Infrastructure and Problematic Stormwater into an Award-Winning Asset

John Magner and **Sam Lee**
Stantec Consulting Services Inc.
John.Magner@stantec.com, samuel.lee2@stantec.com

Stormwater runoff was an ongoing challenge at Lexmark International's corporate headquarters in Lexington, Kentucky. Heavy downfalls on Lexmark's 264-acre campus led to water quality issues and flooding problems in the creek that flows through the property. Lexmark wanted to find an innovative solution that not only achieved their goals of improving water quality in the local watershed, but also saved money by reducing municipal water consumption. The City of Lexington wanted to improve water quality in the area.

The design-build team of Stantec, EcoGro, and Ridgewater (Project Team) initially performed a stormwater best management practice (BMP) feasibility study for the campus. As a result of the study, Lexmark submitted an application for a Lexington-Fayette Urban County Government (LFUCG) Stormwater Quality Projects Incentive Grant to fund the design and construction of a bioretention basin and rainwater harvesting system (RWHS).

The system of new and repurposed infrastructure demonstrates that innovation does not have to undercut a business's profitability. The system diverts rainwater runoff from approximately 35 acres of mostly impervious area into a bioretention basin, where it is infiltrated through sand and soil before draining to a pump wet well. The water is then pumped into one of two repurposed tanks, a 3-million-gallon storage tank or a 500,000-gallon fire water tank for later use. The naturally soft water is used in Lexmark's cooling towers, reducing the need to purchase potable water for use in these processes.

The results of the project have been exceptional. Through August of 2019, 95% of all water used in the cooling towers (over 5,700,000 gallons) was harvested rainwater from the RWHS. While reducing the demand on Lexington's water supply, the project also improves water quality in Cane Run and the Royal Spring's Aquifer, the drinking water supply for Georgetown, Kentucky. In 2019 and 2020, over 11.4 million gallons of treated municipal water – which would otherwise have been used in the campus's cooling towers – was replaced with recycled stormwater.

In addition to contributing to improved water quality, the project continues to educate other corporations and members of the community about sustainable practices for managing stormwater for beneficial reuse, as members of other local corporations and members of the community visit and tour the project and learn about its innovative approach to stormwater management. The result of the project is a man-made, yet naturally inspired system that provides tangible benefits to Lexmark and the community.

The project was awarded the 2020 Kentucky chapter of the American Council of Engineering Companies (ACEC) Grand Conceptor award, the top ACEC award in the state.

Leveraging Intersections: Integrating Watershed Management and Hazard Mitigation Planning to Combat Climate Change

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With the increase in frequency and duration of severe weather events becoming the new normal, communities are facing growing pressure to develop plans that protect vulnerable populations and infrastructure. In Kentucky, and elsewhere around the nation, flooding and water quantity are issues of considerable concern. Within the goals of protecting water quality and controlling water quantity are solutions that are dual purpose, thereby providing a unique opportunity to strengthen mitigation and management efforts. Extreme rain events can exacerbate runoff of water quality-degrading pollutants, such as sediments and nutrients (e.g., Kaushal, *et al*. 2014). Green infrastructure that provides filtration of pollutants from stormwater runoff may also slow flows and improve infiltration reducing erosion and flooding.

Authored every five years, federally-mandated Hazard Mitigation Plans (HMPs) aim to prevent, mitigate, and/or respond to high-risk climate events, like flooding. Successful HMPs build partnerships involving governmental agencies, non-governmental organizations, businesses, and the public; identify management strategies and implementation approaches; increase awareness of hazards through outreach and education programs; and synthesize all these efforts to effectively communicate priorities to leverage funding. These plans tend to involve water quantity-focused initiatives, and historically do not engage in watershed-based management approaches that would integrate water quality considerations.

Like HMPs, Watershed Plan (WSP) development utilizes a phased approach: data collection, assessment and targeting, and strategy development and implementation establishes a plan that reflects the interdependency of natural resource uses, wide-ranging stakeholder interests, and ecosystem functions and services. Analogous to HMPs, they rely on committed stakeholder partnerships, geographic focus, scientifically sound management practices, and coordinated education and outreach strategies. However, water quantity is often not emphasized in WSPs, as their primary goals are to improve water quality metrics.

Given the parallels between watershed and hazard mitigation planning, collaboration can provide a thorough and enhanced planning process that expands available funding sources, better informs selection and implementation strategies, and increases public awareness of the link between water quality and quantity issues. In this presentation, we describe how federal and state agencies partner with universities, regional planners, and municipalities in Kentucky to dovetail watershed and hazard mitigation plans.

Riparian Reforestation for Stream Water Quality Improvement: Evidence from Reforested Urban Sites in Lexington

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Urbanization has been associated with a suite of negative effects to stream health, collectively known as the "Urban Stream Syndrome." While many of these effects are related to watershed-scale factors such as impervious surface area or structural issues such as channel alteration, some impairment is related to loss of healthy riparian plant communities. Urban forests are of interest for a variety of ecosystem services, such as carbon storage, water storage and evapotranspiration, air purification, shade and temperature regulation, and wildlife habitat. Some of these benefits may be additive in riparian areas. For example, streams serve as wildlife corridors in urban areas, so reforesting riparian areas can enhance wildlife corridor quality. Forested riparian buffers may also enhance stream-water quality in urban areas by slowing and processing surface runoff, and taking up nutrients such as nitrate. This study was conducted to evaluate the effectiveness of reforested riparian buffers for enhancing stream-water quality in four streams in Lexington, Kentucky: West Hickman Creek at Veteran's Park ("West Hickman"), two of its tributaries ("Ribbon Park" at Ribbon Park, and "Hickman Tributary" at Veteran's Park), and a tributary of Town Branch ("Kentucky Horse Park"). All four sites were planted with native trees as part of the community reforestation event "Reforest the Bluegrass," and managed by Lexington-Fayette Urban County Government (LFUCG) Environmental Services. Stream-water grab samples were collected upstream and downstream of each reforested reach on a weekly basis from June to October of 2020, with some gaps during low- or no-flow periods for some streams. Stream-water samples were analyzed for a suite of water chemistry metrics by the UK Department of Forestry and Natural Resources Forest Hydrology Lab. Paired t-tests were performed to compare upstream and downstream values for all metrics within each stream. While no significant differences between upstream and downstream values were detected for West Hickman Creek, significant differences ($p < 0.05$) were detected for each of the other three streams. Conductivity, total organic carbon (TOC), alkalinity, and calcium decreased significantly through the reforested reach in the Ribbon Park site, while potassium increased through the reach. Similarly, Conductivity, alkalinity, sulfate, and nitrate decreased through the reforested reach in the Hickman Tributary site. Finally, nitrate significantly decreased and potassium significantly increased in the Kentucky Horse Park site. Significant decreases in nitrate through the reforested reaches at the Hickman Tributary and Kentucky Horse Park sites are especially promising: mean (± 1 SD) upstream nitrate concentrations at these sites were 1.26 (± 0.51) and 1.10 (± 0.68) mg/L, respectively, while downstream nitrate concentrations were 0.93 (± 0.54) and 0.68 (± 0.68), respectively. Mean (± SD) difference in nitrate concentrations were 0.33 (± 0.41) and 0.42 (± 0.36) mg/L, respectively. Nitrate reduction in these small streams is likely related to uptake by riparian vegetation, especially trees, given that these streams are mostly shaded and algal growth is not likely to be a significant factor. These results illustrate the potential of riparian forest buffers to reduce nitrate loads in small urban streams. If scaled up, reforesting small streams in urban catchments could significantly reduce nitrate exports to larger streams, contributing toward mitigation of basin-scale nutrient enrichment issues such as the Gulf Dead Zone.

Red River Gorge, Kentucky Non-Point Source Pollution Program Implementation

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The U.S.D.A Forest Service, Daniel Boone National Forest, in partnership with Kentucky Waterways Alliance, Eastern Kentucky Pride, and Kentucky Division of Water, is currently in the 3rd cycle of a §319(h) grant. The project addresses threats to stream health and water quality on private and National Forest System lands in Wolfe, Menifee, and Powell Counties of Kentucky. The downstream portions of the project watersheds contain the Forest Service-managed Red River Gorge, and the headwaters are privately-owned residences, small communities, and farms. A watershed-based plan identified two main pollutant concerns in the project area: pathogens in the headwaters from failing septic/sewer systems and stream sedimentation in the downstream areas from Red River Gorge recreation impacts. Project milestones from cycle 1 and 2 include: a watershed-based plan, watershed coordinator for the Red River, 85 miles of trails rehabilitated, 86 miles of trash removed from waterways, 400 unauthorized campsites closed, and 14 septic systems installed or repaired on private residences. More accomplishments are expected before the completion of the 3rd cycle.

Session 2B: Groundwater and Karst

In Situ 3D Electrical Resistivity Method for Understanding Water Dynamics in Shallow Karst Features*

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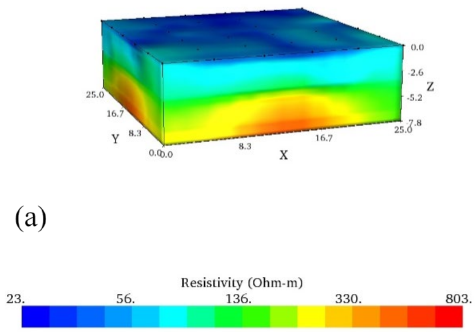
Understanding how water infiltrates and recharges subsurface aquifers is important for protecting groundwater resources. The water infiltration process is complex, however, especially in karst areas where many surface karst features, such as sinkholes and sinking streams, provide different pathways connecting surface water to groundwater. To monitor the water-infiltration process, we deployed time-lapse electrical resistivity surveys with permanently installed electrodes in Royal Spring groundwater basin in central Kentucky.

In a typical electrical resistivity survey, electrodes are placed in the ground during the survey and retrieved after the survey. For this project, we built electrodes that can be installed and left in the field for a long period to improve data accuracy and reduce field work. The electrodes are made using 10-in. stainless steel rods that are tightly wrapped with 18 AWG copper wire and secured with room-temperature vulcanizing silicone and 0.5-in. shrink tubing.

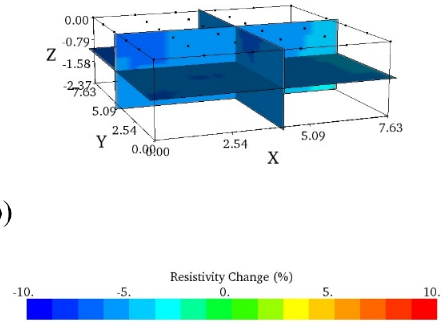
Two in situ electrical resistivity survey sites were established at the Kentucky Horse Park in the middle of Royal Spring basin. One site is at a sinkhole near well 20 and the other in a perched aquifer near well 22. For the sinkhole site, a 6 X 6 grid was used, with 3-ft spacing, and at the perched aquifer site, another 6 X 6 grid was used but with 5-ft spacing. At each site, the electrodes were placed evenly and buried into the subsurface. After burial, the contact resistivity was measured to ensure good connections between electrodes and soil. Field data acquisition focused on various storms; surveys were conducted before, during, and after storms. Daily surveys were conducted for the perched aquifer site between April 6 and April 12, 2021, and for both sites between June 14 and June 25, 2021.

The time-lapse survey data in April for the perched aquifer site showed temporal changes in resistivity corresponded well with precipitation events. There were no obvious resistivity changes in the first three days, when there was little precipitation. A decrease in resistivity occurred on April 10 when rainfall of 0.6 in. was recorded (Figure 1). An additional, but small, amount of rainfall on April 11 further reduced resistivity. The surveys also revealed that the change in resistivity was not uniform.

Our next step will be to analyze the time-lapse survey data collected in June 2021 and compare the results for the two sites. We expect that data will reveal different water dynamics for the two sites and provide insights into how soil water responds to rainfall in karst regions.



(a)



(b)

Figure 1. (a) Inverted resistivity volume for the perched aquifer (well 22) site on April 6, 2021. The depth to bedrock is around 6 ft, with a general trend of increasing resistivity with depth. (b) Percent change of resistivity for the site between April 10 and April 6, 2021. The decreasing resistivity shown in (b) corresponds to rainfall on April 10, 2021.

This presentation is based upon work supported by the U.S. Geological Survey under Grant/Cooperative Agreement No. G20AS00025, WRRI 104B Annual Grant Program.

Identifying the Intersection of Contaminated Karst Water and Off-the-Grid Communities in Southcentral Kentucky Using GIS*

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Amish and Mennonite communities in Kentucky's Pennyroyal Plateau live with limited modern infrastructure, in some cases including water treatment, and rely on karst water sources. The karst landscape offers little or no surface water, and karst springs are likely to be contaminated in this area by agricultural land use.

Previous studies of four family water supply karst springs in Barren and Monroe Counties found that all water samples tested positive for both total coliforms and *E. coli*, bacteria that come from human and/or animal waste. According to World Health Organization guidelines every sample of non-treated water from these springs was classified as *polluted* with respect to water quality and had *high* gastrointestinal health risk. We have identified other areas where families are drinking untreated karst groundwater and, in some cases, have become ill as a result.

There is a good possibility that many more families and communities with limited water treatment in southcentral Kentucky depend on similarly polluted karst groundwater. In order to address this issue, a team of researchers from Western Kentucky University is using Geographic Information Systems (GIS) computer mapping technology to help locate areas where such off-the-grid communities may be relying on contaminated karst groundwater. We are focusing on the 10-county area within the Barren River Area Development District (BRADD) in southcentral Kentucky, which is home to extensive karst terrain and a relatively high density of Amish and Mennonite communities.

We collected data on the physical landscape. GIS information about the geology and hydrology of the BRADD region, as well as groundwater quality, are publicly available through the Kentucky Geological Survey. Layers generated from geological maps outline the extent of carbonate rocks which define the areas of karst terrain, and data showing the locations of springs and wells indicate potential water sources for local communities. Spatial information about the locations of sinkholes suggests areas where pollutants may rapidly enter the underground water supply, potentially rendering the water unsafe to drink.

Geospatial data representing the locations of local off-the-grid communities do not currently exist. As a starting point, we estimated the locations of these communities by searching for businesses, farms, and other locations associated with common Amish/Mennonite/Anabaptist surnames. We also searched for schools, churches, and community centers with the key works "Amish" and "Mennonite". A data point was collected for each establishment, and a five-mile radius was created around each point representing the possibility of an Amish or Mennonite plain community in the vicinity. The five-mile radius represents the average maximum travel for a horse and buggy. These focus points have served as a starting point to direct continuing fieldwork.

**This presentation is based upon work supported by the U.S. Geological Survey under Grant/Cooperative Agreement No. G20AS00025, WRRI 104B Annual Grant Program.*

Groundwater Characterization: How Much Data is Enough?

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Efforts to quantify groundwater properties and behavior often require the use of complex methodologies to uncover the temporal and spatial patterns between different components of the hydrogeologic system. Characterizing groundwater systems using major ions provides a basis for understanding the baseline conditions of a groundwater system to then assess potential impacts to these critical water resources. The use of a variety of multivariate statistical techniques has become a standard procedure in studies on groundwater hydrochemistry and developing an understanding of aquifer types. Each method provides a different insight into the data; however, enough data to run these complex analyses are not always available. We used a combination of multivariate techniques, including principal component analysis (PCA) and hierarchical cluster analysis, to investigate characterization and hydrogeologic grouping of aquifers based on similarities and differences in geochemistry. From these groupings we then determined which and how many parameters can be removed without changing the classifications.

Using a combined PCA–cluster analysis approach, and groundwater-quality data available for 60 well sites spread throughout Kentucky, we identified six distinct groundwater systems. These systems are primarily distinguished by variability in conductivity, sodium, and potassium, and secondarily by calcium and magnesium concentrations and match the previously identified physiographic regions of the state. These data suggest that as a basis for characterizing a groundwater system, at a minimum, these five hydrochemical parameters are essential to collect.

Examining Hydrogeological Dynamics of Baselevel and Reverse Flow of the Green River and Major Springs of Mammoth Cave, Kentucky*

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Mammoth Cave is one of the most studied caves in the world, but lacks hydrological data on the recharge/discharge dynamics of its primary spring outlets, Echo and Styx Springs, during varying moisture conditions and river reversal events. The Green River, which is the primary receiving stream for these springs, can backflood and reverse flow into the springs, causing an influx of river water that can cause contamination and influence the dissolution of the cave. Recharge dynamics of varying storm events and baseflow conditions are also not well understood between the two adjoining springshed basins for Styx and Echo. Data were collected starting in January, 2021 and include weekly water samples for isotope and geochemical analyses at 13 sites on the surface and in-cave, water levels at six sites (four surface, two in-cave), and discharge data for the two springs and Green River. These data were used to determine the conditions during which river reversals occur at the two springs and how epikarst and surface rainfall recharge the system during storm events to create competing hydraulic head pressures. Results from this study aim to improve the understanding of karst groundwater flow and its implications in teleogenetic karst systems under the influence of human impacts, including dams and landuse change. River reversals appear to be moderated by cave recharge dynamics during certain flow conditions to a threshold at which the springs dominate the flow regime, while during high river discharge, the system can exceed this threshold and the Green reverses into the cave via the springs and creates a new hydrologic regime. The system responds within weeks to return to baseflow, except during anomalous flood conditions, which was captured in a February, 2021 major flooding event, indicating that sustained flood conditions overwhelm the springs for longer periods of time. Recharge points in the cave have varying geochemical signatures and indicate the complex residence time dynamics that control the discharge in the springs during different seasons and antecedent moisture conditions. These results have implications for the management of the cave system and adjacent Green River with respect to a variety of hydrologic and biological parameters, including the potential future response under a changing climate.

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Soil Moisture Micronet in the Daniel Boone National Forest

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Recognizing that in-situ soil moisture observations record conditions only at Kentucky Mesonet monitoring sites, the value of those observations is directly related to the representativeness of the Mesonet site. While some simple terrains can be served by soil moisture observations collected at a discrete point, more complex terrains consisting of differing slopes, soils and geology cannot. In these complex terrains, it is not reasonable that a single monitoring site could be broadly representative of the surrounding area. This is the case in Kentucky's Daniel Boone National Forest and more broadly across the Cumberland Plateau. The Daniel Boone National Forest is dominated by the soil order Ultisol, largely of the Udult suborder. It is topographically diverse and representative of the larger Cumberland Plateau.

Thus, we are developing a high-density micro-scale soil moisture monitoring network in the Daniel Boone National Forest. This network will involve the establishment of a micronet with monitoring sites selected to represent the diversity of terrain characteristic of the Cumberland Plateau. The micronet will be designed to monitor and analyze soil moisture-terrain relationships. Thus, soil moisture probes will be installed at topographically diverse positions within a small area. For example, within an area containing a ridge, slopes at various elevations, aspects, and types, and adjoining valleys. The hub of the micronet will be a fully equipped Kentucky Mesonet station sending data back to a live webpage using a cellular network. Micronet stations will communicate with the hub via radio telemetry. Extensive metadata will be collected and strategically catalogued for each station in the network. This project will serve as a pilot for similar networks in other locations, developing standard operating procedures and best practices for intensive monitoring in complex terrains.

This project is funded by NOAA/NIDIS as part of the National Coordinated Soil Moisture Monitoring Network, with additional support from the Daniel Boone National Forest, the USGS Ohio-Kentucky-Indiana Water Science Center, and the U.S. Forest Service Office of Sustainability and Climate.

Session 3A: Watershed Management II

Salinization and Alkalinization of Kentucky Lake: A Result of Human Activity?

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Increased salinization and alkalinization of lakes and reservoirs over the past several decades are well documented for the World's northern regions and are related largely to human activity, particularly the ever-increasing use of road salts. Water quality of Kentucky Lake, the terminal hydroelectric impoundment on the Tennessee River system, has been monitored for a number of water quality parameters since 1988. Trend analyses of variables associated with salinity (chloride and alkalinity) have increased significantly over the past three decades. Cl has increased from 6 mg/L to 10 mg/L, and alkalinity, even though seasonally variable, has increased from 50 mg $CaCO_3$/L to 60 mg/L since 1988. Ca ion concentrations, measured since 2012, doubled from <12 mg/L to over 30 mg/L in 2017 and then decreased to 12-15 mg/L in 2018 and 2019.

The largest source of Ca and Cl ions is likely related to increases in road-salt runoff. Because of the size of the Tennessee River basin (105,870 km^2), determining sources of Ca and Cl remains difficult, but the six Kentucky counties surrounding Kentucky Lake have experienced a 100% increased use of de-icing Cl and Ca brine since 2002. Increasing agricultural liming and wet deposition may be adding to increases in Ca and Cl. Zebra mussels were rare in Kentucky Lake until 2017 when a massive bloom occurred corresponding with high Ca levels. Once the Ca levels dropped below 21 mg/L in 2018, zebra mussels all but disappeared. Reasons for the Ca decrease remain unknown but appear directly related to human activities. The potential long-term effects of increased salinization and alkalinization on the lake ecosystem and the development of conditions favorable for species shifts, such as zebra mussels, are expected to become more apparent as long-term monitoring continues. Data will aid in understanding the long-term patterns of Ca and Cl and their effects on reservoir ecology and biology and will help inform reservoir management protocols in the 21st century.

Tools for Wetlands Assessment and Prioritization: Assets in Abating Nonpoint Source Pollution

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Wetlands are known to provide valuable ecosystem services, including water storage, streamflow and groundwater stabilization, carbon storage, recreation, wildlife habitat, and pollution absorption and remediation. The ability of wetlands to help regulate water quantity issues as well as store and potentially treat pollutants in watersheds make them valuable nature based solutions for nonpoint source pollution abatement (NPS) at a watershed scale. The ability of wetlands to abate NPS is dependent on factors affecting wetland function and watershed organizations often lack access to localized tools that can help them efficiently estimate the health of their wetlands and prioritize potential actions.

Kentucky has lost approximately 81% of its original 1.5-million wetland acres. In order to assess the extent and quality of the state's remaining wetlands, the Kentucky Division of Water (KDOW), in collaboration with other state, federal and university partners collectively known as the Technical Work Group (USFS, KDFWR, USFWS, NRCS, USEPA, KDNR, USACE, KSNPC, KDOW, and EKU), developed the Kentucky Wetlands Rapid Assessment Method (KY WRAM). Metrics of the KY WRAM include size and distribution, buffers and intensity of surrounding land use, hydrology, habitat alteration and habitat reference comparison, special wetlands, and vegetation, interspersion, and habitat features. Although originally created to be used in Clean Water Act Section 401 and 404 permitting decisions, the KY WRAM could be a valuable tool for watershed organizations to assess the health of their wetlands. Additionally, the Kentucky Division of Water also developed the Wetlands Prioritization Tool (WPT) to assist groups in prioritizing wetlands for restoration and protection. The WPT is an Excel model that incorporates KY WRAM data into the decision making process. The tool allows five choices of ecosystem services: general, flood flow alteration, sediment retention, water quality/nutrient removal, and wildlife diversity and abundance. These services were appraised in light of three categories: social significance, effectiveness, and opportunity. The ability to incorporate wetland data and priorities in watershed management could be valuable for groups aiming to increase water health by decreasing NPS in their watershed.

The KY WRAM and WPT have the potential to help watershed groups understand the health of their wetlands and prioritize wetland restoration and protection. This may increase the ability of these organizations, and their associated watersheds, to abate NPS. This presentation will focus on the potential of these tools to be used in projects aiming to reduce NPS at a watershed scale.

Monitoring McConnell Springs Stormwater Quality Wetland Pond and Gainesway Pond Retrofit: 2010-2021

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It has been 12 years since the completion of the McConnell Springs Stormwater Quality Wetland Pond and the Gainesway Pond Retrofit projects by the Lexington-Fayette Urban County Government (LFUCG). The McConnell Springs stormwater project, consisting of a pre-treatment gross debris trap, three settling forebays, a 0.2 acre deep-pool pond, and a 0.5 acre shallow marsh/littoral shelf area, was completed in December 2009. In spring 2009, LFUCG remediated Gainesway Pond at Centre Parkway as part of the Gainesway Retention Basin Water Quality and Environmental Education Project, which consisted of constructed wetlands, aquatic plantings, aeration, and upstream biofiltration/gross debris traps. The purposes of these facilities were to reduce non-point source pollution entering neighboring streams, as a public demonstration of the benefits that natural environments provide to water volume control and quality, and provide the community with environmental educational opportunities. Both of these projects were funded in part through a §319(h) grant provided by the U.S. Environmental Protection Agency and administered by the Kentucky Division of Water.

During the last 11 years, LFUCG Division of Water Quality has been monitoring water quality and determining the effectiveness of pollutant reduction by the two stormwater projects. Five sampling sites were tested at McConnell Springs, sites M1-M3 were located in the pre-treatment and forebay cells and sites M4-M5 were located in the main pond. Five sampling sites were also tested for Gainesway Pond: upstream, mid-stream, wetland area, Pond A, and Pond B (i.e., GP1-GP5). A total of 64 sampling events have been conducted at McConnell Springs and 60 sampling events at Gainesway Pond. On-site measurements included: temperature, pH, dissolved oxygen (DO), conductivity, and total dissolved solids (TDS). Samples also were collected for testing at the laboratory and the additional analysis included: alkalinity, hardness, CBOD5, total suspended solids (TSS), total ammonia, nitrate, nitrite, orthophosphates, total phosphorus, bacterial enumeration, and total metal concentrations. Bacterial enumeration of fecal coliforms, *E. coli*, and total coliforms were conducted using the IDEXX Colilert-18 and Quanti-Tray/2000 method. Metals in water samples from McConnell Springs were analyzed in 2010, 2013, 2014 and 2017 and from Gainesway Pond in 2013, 2014 and 2017.

Water quality parameters in the McConnell Springs stormwater structure were elevated in the 2010-2012 period, however, average concentrations decreased and stabilized as the system became established. Although average dissolved oxygen levels at the stormwater structure were reduced, DO did increase through the facility, with downstream sites M4-M5 having the highest DO. Alkalinity levels averaged 55-64 mg/L and hardness averaged 47-84 mg/L for 2013-2021. Total suspended solids were observed decreasing over time. As expected, highest levels of TSS and TDS were detected in the forebays and decreased in the pond. Average ammonia, nitrate, nitrite, total phosphorous, and orthophosphate concentrations for 2010-2021 decreased at sites M4-M5. Reductions in bacterial counts at sites M4-M5 also were observed in 2010-2021. Levels of *E. coli* peaked in June 25, 2014, however, both fecal coliforms and *E. coli* counts have decreased. Of the 30 metals tested in 2010, the concentrations of Al, Cu, Fe, Ni, S and Zn decreased through the stormwater facility. With the exception of sulfur, all detectable metal concentrations decreased in 2013, 2014, and 2017. Metals not detected in 2013 included Ag, Cd, Ni, and Zn.

At the Gainesway Pond stormwater structure the lowest DO levels were observed at the wetland site (GP3), but increased in the downstream ponds (GP4-GP5) in part due to the addition of an aeration fountain and underwater bubbler. Total alkalinity has remained stable since 2013 with average concentrations of 185-208 mg/L. Whereas, hardness has been decreasing over time, with lower concentrations observed in 2018-2021. Conductivity, alkalinity, and hardness concentrations decreased at sites GP4-GP5. As expected, average TSS concentrations were highest in the wetland area and downstream ponds. Yearly averaged TSS levels were elevated in 2015 (mainly at GP3), but the concentrations have decreased in subsequent years. Ammonia and total phosphorous concentrations were elevated in February 19, 2014, but have decreased over time. Increased total phosphorous and orthophosphate concentrations were detected in the downstream ponds. Levels for nitrate and nitrite peaked in 2010, decreased in 2011, and have since remained fairly constant. Both fecal coliforms and *E. coli* yearly average counts have decreased during the 11 years of monitoring. Bacterial counts were generally largest at upstream sites and decreased in the ponds. Metals not detected in 2013 included Ag, Cd, and Zn. Concentrations for Fe, Mg, Mn, Ni, K, and S were highest at GP3.

Since their completion, and based on 11 years of monitoring data, the stormwater structures have improved incoming water and are performing efficiently. Consistent results are being obtained as the systems have stabilized over time. Reductions of several pollutants were observed at both facilities. Of interest were the reductions in bacterial counts over time, and decreased water metal concentrations through the systems. These reductions aid in decreasing urban stormwater impacts on neighboring streams. LFUCG will continue to monitor water quality in these projects. In particular, close monitoring of ammonia, total phosphorous and bacterial counts which can have detrimental impacts to the stormwater structures and receiving waters. In addition to improvements in water quality, both stormwater structures have provided the community with educational opportunities and have enhanced these public recreational areas.

Session 3B: Sediments and Nutrients

Starter Fertilizer Impacts on Turfgrass Establishment and Quality

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Home lawns are a significant contributor to surface water degradation due to nutrient runoff from fertilizers. Fertilizers high in phosphorus (P) are commonly used in lawn establishment, regardless of soil P levels. We determined the effects of starter P fertilizer on the establishment (coverage) and overall turfgrass quality on high P (Bluegrass; fine-silty, mixed, active, mesic Typic Paleudalf; Mehlich 3 (Meh3) extractable P = 430 lbs. ac^{-1}) and low P (Sadler; fine-silty, mixed, semiactive, mesic Oxyaquic Fraglossudalf; Meh3 P = 16 lbs. ac^{-1}) soils. Twelve pH adjusted soil box-plots, 6 with Bluegrass and 6 with Sadler, were seeded with tall fescue (*Festuca arundinacea* Schreb.) at a rate of 7 lbs. 1000 ft^{-2}. Three box-plots of each soil were fertilized using a commercially available starter fertilizer (24-25-4) according to manufacturer recommendations (3 lbs. per 1000 ft^2) . Box-plot images were collected weekly using a light box and images were evaluated for percent cover and turf quality using software (Turf Analyzer). There was no significant difference in percent cover between the two treatments (starter P versus no starter P) on the same soil from weeks 3 through 8 after seeding. Bluegrass with starter fertilizer box-plots had significantly greater overall turfgrass quality than Bluegrass without starter box-plots in week 8, but by the end of the experiment, week 11, there was no significant difference in overall quality between the two treatments. Starter fertilizer did not increase turfgrass cover nor improve overall quality on naturally high or low P soils under the controlled conditions used in this experiment.

**This presentation is based upon work supported by the U.S. Geological Survey under Grant/Cooperative Agreement No. G20AS00025, WRRI 104B Annual Grant Program.*

Blue Water Farms: Edge-of-Field Monitoring of Nutrient and Sediment Loss from No-Till Corn and Soybean Fields in the Lower Green River Watershed

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Nutrient (nitrogen and phosphorus) and sediment derived from urban construction as well as food production activities are leading contaminants resulting in stream and river impairment in Kentucky. While agricultural producers commonly employ best management practices (e.g., crop rotation, cover crops, no-till, etc.) to mitigate nutrient and sediment losses to retain nutrients in-field, studies evaluating the efficacy of best management practices on the reduction of nutrient and sediment in agricultural runoff are limited in western Kentucky. To further understand the relationships between agronomic practices and water quality, researchers from the University of Kentucky have collaborated with the U.S. Department of Agriculture Natural Resources Conservation Service, Kentucky Soybean Promotion Board, Kentucky Agriculture Development Board, and Kentucky row-crop producers to conduct edge-of-field water quality monitoring in the lower Green River watershed. This project is part of a national effort to evaluate the efficacy of best management practices and assist the agricultural community in making informed nutrient management decisions.

Watershed analysis was conducted in the lower Green River watershed to identify 10 watersheds within no-till corn/soybean rotation fields. LIDAR and survey data were used to subdivide the fields into 5 control watersheds and 5 treatment watersheds ranging in size from 3 to 12 acres. In each watershed, a monitoring station was instrumented with a flume, ultrasonic flow sensor, flow meter, rain gauges (manual and tipping bucket) and a composite water sampler.

Year-round sampling of surface water runoff from no-till corn/soybean fields to monitor changes in nutrient and sediment loads is in progress. Data will be collected over a 10-year period, including 2 years of baseline data (calibration period) and 8 years of control/treatment data. In 6 paired watersheds, the control (current agricultural practice) is broadcast poultry litter and the treatment (best management practice) is poultry litter incorporation. In 4 paired watersheds, the control watersheds will be planted with a wheat cover crop, while the treatment watersheds will be planted with a cereal rye cover crop after the calibration period.

The results of this project are expected to help agricultural producers implement best management practices that reduce erosion and improve on-farm nutrient retention in Kentucky. Monitoring data are also expected to be utilized for modeling nutrient and sediment losses under differing farm management practices. If effective best management practices are implemented on a larger scale, this project may guide efforts to mitigate sediment pollution and downstream eutrophication (e.g., the Northern Gulf of Mexico Hypoxic Zone).

Blue Water Farms: Edge-of-Field Monitoring of Nutrient and Sediment Loss from Wetland Watersheds in the Northern Mississippi Embayment

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Wetland conservation easements are promoted by the U.S. Department of Agriculture Natural Resource Conservation Service to return floodplains and other flood-prone, row-crop agricultural fields to natural vegetation to filter nutrients and sediments in surface water runoff prior to reaching a stream or river. We propose to evaluate the soil phosphorus content of established wetlands of different ages. We hypothesize that nutrient stratification common in agricultural fields will be less prominent in older wetlands relative to younger wetlands. Seven small watersheds, less than 12 acres, within different aged, western Kentucky wetlands were selected: three watersheds less than 1 year old, two watersheds between 5 and 10 years old, and two watersheds between 30 and 40 years old. Soils were sampled with a pneumatic probe or hand auger on a 10x10 m grid at three depth intervals: 0-10 cm, 10-30 cm, 30-60 cm. Total phosphorus (microwave digest) and plant available phosphorus (Mehlich 3 extraction) were determined on each sample and spatial analyses was conducted using ArcMap. Results will be discussed spatially within each watershed with depth and temporally across all wetlands.

Poster Session

1. Advancing Prediction of Headwater Flow Permanence and Stream Expansion and Contraction Using a Process-Based Hydrologic Model

Tyler Mahoney[1], Jay Christensen[2], Heather Golden[2], Chuck Lane[2], Grey Evenson[2], Ellie White[3], Ken Fritz[2], Ellen D'Amico[4], Chris Barton[5], Tanja Williamson[6], Kenton Sena[7], Carmen Agouridis[8]
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Streamflow in headwater systems supports both ecosystem functioning and water quality across stream networks by facilitating hydrologic connectivity between upstream and downstream watershed compartments. Additionally, knowledge of streamflow permanence characteristics in headwaters is particularly important for their federal protection. However, characterization of the frequency, magnitude, and duration of flow in headwater streams remains limited – largely due to the scarcity of both monitoring efforts and the development of process-based models to understand streamflow in these types of systems. Recent advancements in process-based, semi-distributed hydrologic models show promise for characterizing streamflow in headwater systems where data collection may be difficult, but this is largely untested at catchment scales. The objectives of this study were to: (1) develop and test an approach for simulating the frequency, magnitude, and duration of headwater streamflow with a process-based, semi-distributed hydrologic model and (2) apply model outputs to map the spatiotemporal dynamics of headwater expansion and contraction throughout the stream network.

We modified and applied a highly resolved hydrologic model (Dynamic TOPMODEL) to a 1-km2 headwater network in University of Kentucky's Robinson Forest, located in the Appalachian region of Kentucky. We evaluated model performance using discharge data at the watershed outlet, reach-scale flow-state sensor data, and observed headwater extent collected from field reconnaissance. The model framework performed well at simulating flow across the watershed uplands and characterized important stream dynamics within reaches at a high spatiotemporal resolution. The model successfully estimated the probability of streamflow permanence at the reach scale and simulated network scale dynamics of streamflow expansion and contraction. This study underscores the potential for watershed-scale, process-based hydrologic models to characterize headwater streamflow dynamics in systems throughout the eastern United States.

2. Developing ANN Model for Predicting Lake Michigan E.Coli Counts

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During beach goers season, Indiana Department of Environmental Management (IDEM) conducts regular beach sampling at different beaches located in the southern tip of Lake Michigan. Using the test results, beach advisory is made. As this procedure requires time to get E.Coli results, efforts were made in the past to develop E.Coli prediction model using other information to develop an instantaneous decision. In this research work, efforts are made to develop a functional approximation model using Artificial Neural Network model to predict E.Coli. For accomplishing this model development, sampling was conducted in five beaches of Lake Michigan during 2019. During this sampling work, along with water sample for E.Coli, other variables such as total dissolved solids, total dissolved solids, pH, Electrical conductivity, water temperature, beach conditions such as pet counts, beach visitor counts, wave conditions, other meteorological parameters such as humidity, rainfall, temperature, flow observations in creeks draining to southern end of Lake Michigan. After consolidating the data, using different training algorithms, ANN models were developed by dividing the data into training, testing and validation data sets. E.Coli outputs were predicted as classified outputs by dividing the E.Coli into 4 categories.

Category 1:	0 to 125 –	Safe
Category 2:	126 -235 –	Advisory – still safe
Category 3:	236- 799 –	Unsafe
Category 4:	> 799 –	Highly unsafe

Overall, the results indicate 65 % of predicting ability.

Acknowledgement:

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3. Examining Long Term Trends in Rainfall and Stream Flow at Upper Wabash River Basin Using Self Organizing Map

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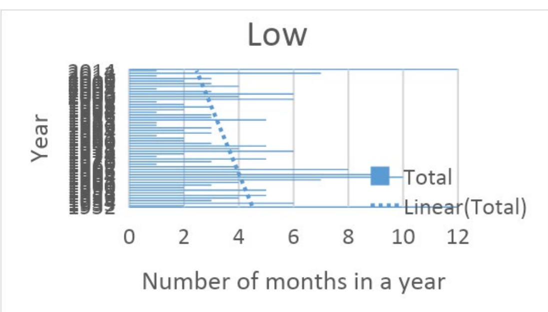
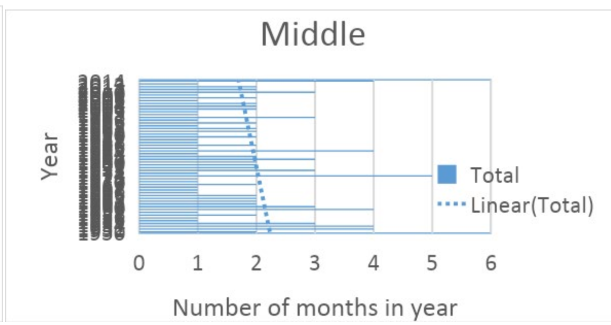
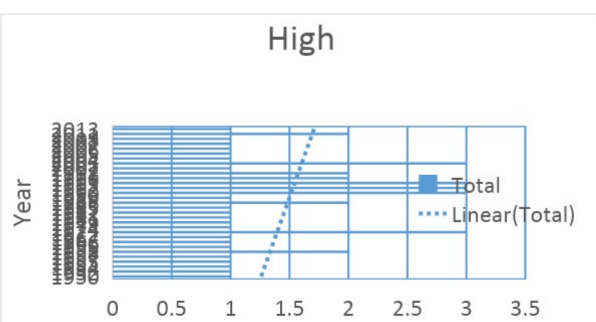
Self Organizing Maps (SOM) is an artificial intelligence technique which is popularly used to cluster similar data during data mining. This tool is also used in the past by researchers to study the long term trends in hydrologic variables. SOM models function differently than the regular ANN models, which are popularly used as a functional approximation tool. The SOM model uses a predefined topology set by users and clusters the data to different neurons during training process. It functions as an effective clustering algorithm. Data associated with each neuron are similar in characteristics. By grouping adjacent neurons, regional data can be grouped into different categories to examine trends. In this study, Upper Wabash River Basin in Indiana was considered. This watershed is located in the central Indiana region. Wabash river is a major tributary to Mississippi-Missouri river system. In stream flow analysis, 12 USGS flow observation stations located in this watershed were considered. These stations cover several tributaries and main stream. To make the data consistent, monthly data from 1950 to 2015 were considered. In a similar way, for the rainfall analysis, monthly rainfall data for 5 counties were used in another trial to group months into different clusters using SOM. Both these results were examined together to study the long term trends. For examining the trends, number of months for each cluster in each year were captured for Low flow, Medium flow and High flow categories. Low flow magnitudes show a declining trend in the recent past, but the high flow clusters shows an increasing trend.







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4. Investigating Water and Sediment Transport Processes with High-Resolution Sensor Measurements and Hysteresis Analysis in the Cane Run Royal Spring Basin, Kentucky, USA

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During storm events, a large amount of water and sediment is mobilized. One way to analyze the behaviors is to use hysteresis. Hysteresis analysis has been used extensively to investigate the behaviors of nutrients and sediments in storm events in surface streams. Discharge vs. sediment concentration hysteresis can give insight into how sediment is distributed throughout the watershed catchment, while electrical conductance vs. sediment concentration tells a story about the deposition or reuptake of sediment. Less research has been carried out in karst settings, which can be of great benefit to understand the characteristics of sediment transport in underground fractures and caves. Recent developments of high-resolution sensors also make it possible to collect a wide variety of water quality parameters to be monitored more feasible than previously. Electrical conductivity sensing provides an approach to water origin tracing, and turbidity sensing provides a surrogate to estimate sediment pulses through hydrologic systems.

Our goal is to gain an understanding of hydrologic transfers in karst basins, especially the transfer of water and sediment analyzed via hysteresis, and to use this information for developing a predictive model of daily water and sediment loads daylighting at a karst spring. This study is investigating a karst spring located in the inner bluegrass area of central Kentucky, which is known for its high karst potential and mature karst development. The Royal Spring basin is located between the city of Lexington and the city of Georgetown and functions as the primary drinking water source for Georgetown while draining the Cane Run Royal Spring basin. Several high-resolution sensors have been deployed at the spring and across the basin for the past 10 years and have collected data in 10-minute and 15-minute intervals. Flow data has been measured and calculated with a Marsh-McBirney 201-D velocimeter or obtained by downloading the data from the corresponding United States Geological Survey gage station. Sensor data was collected with a YSI 6920 V2-2 Multiparameter sonde, a YSI 6600 V2 Multiparameter sonde, and two YSI 600 OMS V2 Optical Monitoring sondes.

This data made it possible to learn about the transport mechanisms in the aquifer and determine the differences between subsurface sediment transport and surface sediment transport in the Cane Run Royal Spring basin. During storm events, water and sediment are transferred from the surface stream network to the karst aquifer and primary cave via numerous swallets in the creekbed. The hydraulic forces produce a fast-response water discharge peak at Royal Spring followed by the delivery of surface water and sediment at the spring 6 to 18 hours later. Water-sediment hysteresis analyses show counterclockwise behavior, which is less widely reported in hysteresis studies, but based on further analyses of data reported by others appears to be a consistent behavior of karst aquifers. Turbidity-conductivity hysteresis suggests either sediment is resuspended in the cave during the initial pressure pulse or the concentration of sediment in water entering the karst cave via the swallets is varying pronouncedly across the event. Un-mixing analyses are ongoing to estimate which process is controlling for this system. Comparison of karst basins across five continents is ongoing. The development of predictive water transfer and sediment load models is also ongoing.

5. Blue Water Farms: Edge-of-Field Water Quality Monitoring of Nutrient and Sediment Loss from No-Till Corn and Soybean Fields in the Lower Cumberland River Watershed

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Nutrient (nitrogen and phosphorus) and sediment derived from urban construction as well as food production activities are leading contaminants resulting in stream and river impairment in Kentucky. While agricultural producers commonly employ best management practices (e.g., crop rotation, cover crops, no-till, etc.) to mitigate nutrient and sediment losses to retain nutrients in-field, studies evaluating the efficacy of best management practices on the reduction of nutrient and sediment in agricultural runoff are limited in western Kentucky. To further understand the relationships between agronomic practices and water quality, researchers from the University of Kentucky have collaborated with the U.S. Department of Agriculture Natural Resources Conservation Service, Kentucky Soybean Promotion Board, Kentucky Agriculture Development Board, and Kentucky row-crop producers to conduct edge-of-field water quality monitoring in the lower Green River watershed. This project is part of a national effort to evaluate the efficacy of best management practices and assist the agricultural community in making informed nutrient management decisions.

Watershed analysis was conducted in the lower Cumberland River watershed to identify 12 watersheds within no-till corn/soybean rotation fields. LIDAR and survey data were used to subdivide the fields into 6 control watersheds and 6 treatment watersheds ranging in size from 3 to 10 acres. In each watershed, a monitoring station was instrumented with a flume, ultrasonic flow sensor, flow meter, rain gauges (manual and tipping bucket) and a composite water sampler.

Year-round sampling of surface water runoff from no-till corn/soybean fields to monitor changes in nutrient and sediment loads is in progress. Data will be collected over an 8-year period, including 2 years of baseline data and 6 years of control/treatment data. In the 12 paired watersheds, the control watersheds will be planted with a wheat cover crop, while the treatment watersheds will be planted with a cereal rye cover crop after the calibration period.

The results of this project are expected to help agricultural producers implement best management practices that reduce erosion and improve on-farm nutrient retention in Kentucky. Monitoring data are also expected to be utilized for modeling nutrient and sediment losses under differing farm-management practices. If effective best management practices are implemented on a larger scale, this project may guide efforts to mitigate sediment pollution and downstream eutrophication (e.g., the Northern Gulf of Mexico Hypoxic Zone).

6. Determination of Microcystin Cyanobacterial Toxins in Kentucky Lakes by Diffusive Gradients in Thin Films*

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Numerous public health advisories have been issued at several KY lakes and reservoirs due to elevated cyanotoxin concentrations, particularly microcystins, which are cyclic peptide hepatoxins produced by several cyanobacterial genera including primarily *Anabaena*, *Microcystis*, and *Planktothrix* (Fig. 1).

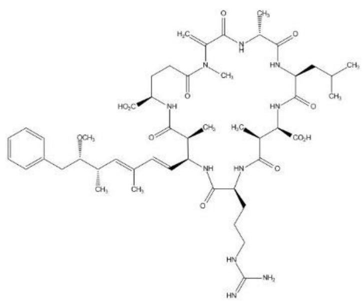
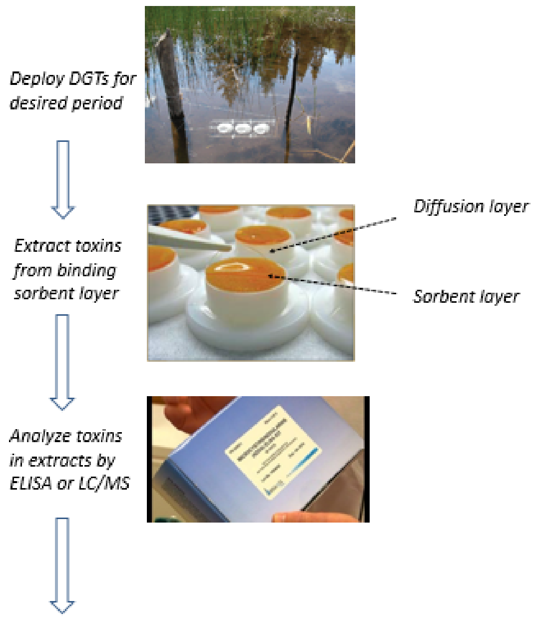


Figure 1. Structure of microcystin-LR, the most commonly detected cyanotoxin in KY lakes.

The traditional approach for collecting water samples for cyanotoxin determination is point-in-time grab sampling, which is useful for determining total cyanotoxin concentrations at a particular point-in-time, but on the downside, grab sampling is not able to determine cyanotoxin concentrations over a longer period without intensive sampling, which makes grab sampling too impractical and expensive for making accurate risk assessments.

To overcome the shortcoming of grab sampling, passive samplers have been developed which typically contain a sorbent that continuously accumulates toxins in water during the sampler deployment period, which is typically several weeks. The most common type of passive sampler for detecting cyanotoxins in water is the "Solid Phase Adsorption Toxin Tracking" (SPATT) sampler which contains sorbent in a mesh bag which accumulates cyanotoxins, which can then be extracted and analyzed with concentrations expressed on a mass sorbent basis. The main benefit of SPATT sampling is its ability to detect presence/absence of cyanotoxins in the water, but has the shortcoming that cyanotoxin concentrations in the sorbent are not related to concentrations in water, which makes results difficult to interpret for health advisory purposes.

Another type of passive sampler, referred to as Diffusive Gradients in Thin Films (DGT), overcomes the weaknesses of grab and SPATT sampling by including a diffusion layer of known thickness over a sorbent layer which allows cyanotoxin concentration in the water to be related to cyanotoxin mass in the sorbent layer by Fick's First Law of Diffusion (Fig. 2) (D'Angelo, 2019. Development and evaluation of a sensitive Diffusive Gradients in Thin-Films (DGT) method for determining microcystin-LR concentrations in freshwater and seawater. Harmful Algae, 89:101688).



$$\text{Toxin concentration in water} = \frac{\text{Toxin mass in sorbent layer x Thickness of diffusion layer}}{\text{Area of sampler x Time x Diffusion coefficient in diffusion layer}}$$

Figure 2. Overview of the Diffusive Gradients in This Films passive sampler method which will be used to determine microcystin concentrations in eight KY lakes during the summer 2021 harmful algal bloom season.

The main objective of this study was to determine microcystin concentrations in eight KY lakes using DGT samplers and enzyme linked immunosorbent assay (ELISA) analysis and to relate microcystin concentrations to water quality properties during the summer 2021 harmful algal bloom season. Another goal is to train undergraduate environmental scientists in limnological research and provide them opportunities to present results at scientific conferences sponsored by KWRRI and University of Kentucky Office of Undergraduate Research.

This presentation is based upon work supported by the U.S. Geological Survey under Grant/Cooperative Agreement No. G20AS00025, WRRI 104B Annual Grant Program.

7. Environmental Conditions on the Lower Ohio River with Comments on Phytoplankton Assemblages

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The Ohio River has had a long history of water quality problems and is considered one of the top 10 most polluted rivers in North America. The river has experienced severe noxious cyanobacteria blooms in recent years, particularly in upstream regions from Huntington, WV, and Cincinnati OH, sometimes extending downstream of Louisville, KY. As part of a larger study to predict potential causes of toxic cyanobacteria blooms on the Ohio River, this study describes water chemistry and phytoplankton community dynamics at two shoreline sampling sites on the lower river; one at Paducah, KY, immediately downstream from the mouth of the Tennessee River and one directly across the Ohio at Brookport, IL. The study area represents the downstream end of the 1575 km long Ohio River, the width of which can exceed 3.2 km during flooded conditions.

Water samples for nutrient analyses were collected every 16 or 32 days in coordination with the long-term monitoring program at Hancock Biological Station (HBS) from January 2017 through October 2020. Physicochemical parameters (temperature, dissolved oxygen, turbidity, pH, ORP, and specific conductance) were measured using a YSI multiparameter sonde at the 1 m depth. Ammonium, nitrate+nitrite-N, total nitrogen, soluble reactive phosphate, total phosphorus, sulfate, chloride, silica, calcium, and chlorophyll a were analyzed using APHA and U.S. EPA methods. Phytoplankton samples were identified to genus using a Zeiss Axioplan microscope (400X mag, Palmer-Maloney cell). Analysis of variance (ANOVA) was carried out on water quality data using SYSTAT 13.2.01 for Windows (2017); additional analyses of phytoplankton data (e.g., PCA, CCA) were carried out using XLSTAT (2021).

Temperature, dissolved oxygen, and pH patterns showed no difference between the two sites. All other variables were significantly different between the Brookport and Paducah sites (2-factor (site, season) ANOVA, p values ≤ 0.05). Specific conductance, turbidity, nitrate+nitrite, total nitrogen, total phosphorus, sulfate, chloride, and calcium ions were significantly higher at Brookport than at Paducah. Soluble reactive phosphate was significantly higher at Brookport during spring; ammonium was higher only during fall with much variation in both parameters during other seasons. Silica was significantly higher at Brookport during all seasons except summer. Chlorophyll α also was significantly higher at Brookport during summer and fall than at Paducah. We attribute the differences to represent downstream accrual of ions and nutrients from upstream sources in the mainstem Ohio River at Brookport and the "cleaner" inputs of more dilute inflow from the Tennessee River just upstream of the Paducah site.

Three major algal classes, Bacillariophyceae, Chlorophyceae, and Cyanobacteria, represented the dominant taxa at both sites. Representatives of other classes, the Euglenophyceae, Cryptophyceae, and Dinophyceae, and Ochrophyceae were all < 5% of the total. A total of 81 genera were collected at Paducah and 77 genera at Brookport. Similarity index (SI) (e.g., coefficient of community) between Paducah and Brookport was 0.93 indicating the two sites were very similar in composition. The diatoms (Bacillariophyceae) far outnumber (as % of total cells) all other taxa at both sites (ranging 60%−80% at Paducah and highest during winter; and 60%−70% at Brookport and highest during spring). The Chlorophyceae were the next most numerous class ranging from 10%–20% of the total cells at both Brookport and Paducah and fairly consistently represented throughout the year. Cyanobacteria ranged from 5%–22% and were highest during summer and winter at Brookport and 5%–25% of the total at Paducah and highest during summer. The top five genera with highest relative abundances at Paducah were *Aulicoseira* (37.1%), *Navicula* (9.2%), "coccoid" chlorophyceans (11.4%), *Cryptomonas* (11.4%), and *Microcystis* (6%). The top five genera with highest relative abundances at Brookport were *Aulicoseira* (34.3%), *Cyclotella* (7.1%), *Synedra* (12.1%), "coccoid" chlorophyceans (10.6%), and *Pseudanabaena* (9.8%).

Temperature was the most important driver of each of the abundances of major taxa. While the water chemistry between the two sites was significantly different, phytoplankton assemblages were quite similar. Further exploratory analyses of potential physicochemical drivers of phytoplankton abundance or community structure did not reveal significant trends.

In conclusion, when the Brookport and Paducah phytoplankton assemblages are viewed within the construct of ecological "functional groups", the most common groups typically are representative if the lower reaches of very large rivers (turbid, slow flow, high light at the surface, lower light penetration at depth). At no time during the study period were the Cyanobacteria or other potential HABs taxa found to be either dominant components or in bloom conditions in this area of the Ohio River. We attribute this to the fact that pooling (stagnation) does not occur here, nor are nutrients in concentrations high enough to support the exponential growth of cells to reach bloom conditions. This study presents updated algal and water chemistry information for the lower Ohio River.

Funding was provided by NSF-EPSCoR (Track 2−OIA#1632888).

8. Restoring Kentucky Streams Containing the Threatened Arrow Darter

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A mitigation sponsor, Ecosystem Investment Partners (EIP), partnering with Kentucky-based engineering and construction firms, Beaver Creek Hydrology (BCH) and Stream Restoration Specialists (SRS), has achieved a milestone in the environmental restoration sector in the state of Kentucky. EIP's 930-acre mitigation bank in Breathitt County, Kentucky, has successfully restored 800 linear feet of habitat specific to the federally threatened Kentucky arrow darter (*Etheostoma spilotum*) and received an Outstanding State Resource Water (OSRW) designation from the Kentucky Division of Water (KDOW). The reach was nominated in 2018 and officially listed as an OSRW on January 3rd, 2020. This designation has not yet been granted to any other private mitigation bank projects in the state.

The restored reach is part of the North Fork of the Kentucky River Stream Mitigation Bank located in the Frozen Creek watershed near Campton, Kentucky. The Mitigation Bank has restored 107,540 linear feet of previously degraded stream. The project area was previously used for farming, grazing, and logging but is now comprised of over 20 miles of restored and permanently protected headwater streams.

To facilitate the recovery of the Kentucky arrow darter within the Graham Branch watershed, the project used Natural Channel Design methods to replicate their ideal habitat. Design features included increased run/glide habitat, shaded pools, and establishment of native riparian vegetation that is typically found in conjunction with stable populations of the darter (i.e. eastern hemlock and rhododendron). The effects of upstream restoration have also contributed to the success of the arrow darter through the significant reduction of sediment and increased water retention.

Field sampling efforts were led by Mike Floyd, PhD., with the Kentucky Ecological Field Office of the U.S. Fish and Wildlife Service (USFWS). Three surveys have been conducted to monitor the population of the Kentucky arrow darters throughout the restoration project. A pre-construction survey on November 17, 2016 initially identified four adult Kentucky arrow darters in the downstream reaches of Graham Branch. A second survey was conducted a year after construction on December 6th, 2018 and identified a total of 5 Kentucky arrow darter individuals. The most recent sampling event took place on August 24, 2020 and identified eighteen Kentucky arrow darters as well as two individuals that were observed but not captured. Both post-construction surveys have shown the migration of the arrow darter further upstream than the initial survey in 2016. Figure 1 shows the size-frequency histogram for the eighteen individuals captured during the 2020 sampling event. These data demonstrate the presence of two distinct age classes (juvenile and adult) on the site indicating successful reproduction and recruitment in 2019 and 2020. The increase in the total number of individuals and the proliferation of juvenile individuals, as well as the expanded range of the fish, suggest that the restoration project has successfully improved arrow darter habitat on the site.

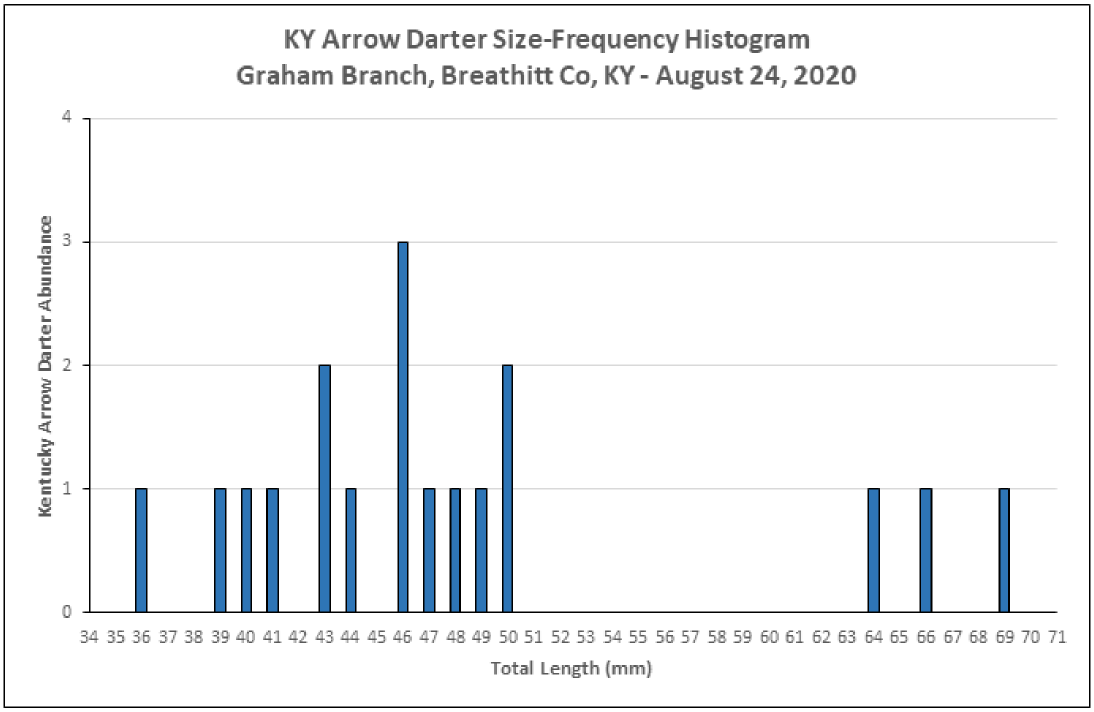

Figure 1. Size-frequency histogram for Kentucky arrow darters collected in Graham Branch during the 2020 sampling event three years after construction.

9. Comparisons of Conductivity and Chloride Concentrations in the Upper Ohio River Valley During Summer and Winter Months

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During hot and dry summers, streams are affected by high water temperature that may lead to low flow conditions that could increase conductivity concentrations and stress stream organisms. During the winter the use of road salts can increase chloride and conductivity concentrations in streams through runoff of salts from impervious surfaces. We collected water chemistry data weekly throughout the Upper Ohio River Valley near Wheeling, WV over the last two years and examined summer and winter trends in conductivity and chloride. We defined summer as June 1st through September 30th and winter as December 1st through February 29th. In the winter of 2020 (December 2020 to February 2021) 90% of the sites had significantly higher chloride levels compared to the winter of 2019 (December 2019 to February 2020). Conductivity concentrations in 2020 were significantly higher at 57% of the sites than in 2019. During the summer of 2020 chloride levels were significantly higher at 50% of the sites compared to the summer 2019. Conductivity concentrations at 58% of the sites were significantly higher in 2020 than in 2019. If these patterns continue, we should expect to see higher conductivity and chloride concentrations becoming more common.

10. Development and Optimization of Green Polymer and Solvent-Based Ultrafiltration Membranes for Water Treatment Applications

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Polymeric membranes are commonly utilized for water treatment applications and are fabricated via phase inversion due to the ease in altering the permeance and selectivity; nonsolvent phase-induced separation (NIPS) is regarded as the dominant phase inversion method. However, one critical drawback is the use of petroleum-based solvents that pose significant hazards to human health and the environment. Moreover, the nature of traditional solvents increases the overall environmental impact of membrane technology, including the large-scale generation of membrane fabrication wastewater that typically undergoes minimal treatment to remove solvents. As such, regulations on solvent use have recently increased and further motivate the need to develop polymeric membranes with green properties (i.e., non-hazardous, recyclable, bio-derived, and/or biodegradable characteristics).

Among potential green solvents, Methyl-5-(dimethylamino)-2-methyl-5-oxopentanoate (Rhodiasolv® PolarClean) and γ-valerolactone (GVL) are considered ideal candidates for membrane fabrication due to their intrinsic properties. The sustainability of membranes can be further enhanced by using recycled polymer materials, namely polyethylene terephthalate (PET) due to its excellent thermal and chemical resistance properties. Moreover, integration of PET into membrane fabrication could create a high-value niche application for PET recycling and reduce plastic pollution.

In this study, PET-PolarClean-GVL ultrafiltration membranes were fabricated via NIPS and compared to other polymeric membranes. In addition to measuring water flux and BSA rejection, evaporation time was altered during NIPS to study its effect on these parameters; membrane characterization was conducted using FTIR and SEM microscopy to analyze the morphology. The end-products of this study are ultrafiltration membranes for water treatment applications with adequate performance parameters and green properties to reduce environmental impacts, as well as guidance for the fabrication and optimization of green polymeric membranes.

11. Municipal Water Quality Concerns and Rebuilding Trust in a Rural Community

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Introduction: A community engaged research approach was used to explore customer perceptions of municipal water quality, accessibility, and affordability in a rural Appalachian county with a complex history of environmental and socioeconomic challenges.

Methods: Academic researchers and community members collaborated to develop and administer a survey instrument that included a health survey and seven open-ended questions. A stratified random sample of 73 water district customers responded. Interview transcripts were iteratively coded and analyzed for emergent themes using NVivo 12 (QRS International) software.

Results: The data suggested respondents generally perceived water quality as poor and only 12% used their tap water for drinking. Many felt they had insufficient knowledge regarding tap water and used a wide range of news and social media sources to access water-related information. Themes of historically-rooted distrust of the water district and local leadership emerged as did perceived inequities for customers.

Implications for Public Health: Opportunities to rebuild public trust through stakeholder engagement and multidirectional risk communication are explored.

12. Application of a Water Treatment Inspired Technique on a 3D Support for Air Filtration

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The Covid 19 pandemic has led to growing demands for personal protective equipment (PPE) to effectively control the spread of the virus. Facemasks are an effective defense against aerosols containing pathogenic bacteria and viruses such as Sars-Cov-2. Membrane filters have been used extensively in face masks to remove these microbes from the air. These filters are usually designed for single-use due to inadequate and laborious cleaning/decontamination techniques. This work attempts to make a breathable antiviral face mask by immobilizing silver nanoparticles (AgNPs), which could suppress bacterial and viral activity on a cellulose acetate (CA) membrane filter required for mask production. AgNp was chemically immobilized by attaching a polymerized epoxy, glycidyl methacrylate (GMA) to CA, allowing for more functionalization of the CA/GMA copolymer. Cysteamine was then combined with the CA/GMA complex, providing thiol groups that immobilized AgNP's on the membrane surface. FTIR analysis confirmed the successful polymerization of the monoGMA, while electron microscopy and X-ray energy dispersive spectroscopy was used to verify the presence of silver on the CA membrane surface. The resulting membrane filters are quite thin and require support for use in mask production. We have used a 3D printed support to ensure strong membrane filters for mask production in this work. An airflow test was carried out on the unmodified CA membrane on a 3D support to ensure breathability. A high airflow resistance was observed through the membrane at pressures up to 10psi. This was hypothesized to be due to small pore sizes inherent in biobased membranes. Therefore, polyethylene glycol (PEG), an organic chemical known to form pores in membranes, was introduced in the dope solutions, and subsequent increases in pore sizes and air permeability were observed.

13. Comparison of Leaf Litter Bag and Environmental DNA in Detection of Salamanders in Maywoods Environmental and Educational Laboratory

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Environmental DNA (eDNA) utilizes DNA released from aquatic organisms into the environment to detect their presence and provides an effective, non-invasive method to survey organisms in an efficient manner. While the majority of early eDNA studies focused on single species presence/absence, a number of more recent studies suggest a relationship between eDNA levels and biomass. This observation has generated considerable interest in the relationship between traditional sampling methods and eDNA, considering the potential benefits of eDNA in enhancing the ease of organism detection. We will survey the salamander community of Maywoods Environmental and Educational Laboratory (Garrard and Rockcastle County, KY) using both traditional (leaf litter bags) and molecular (eDNA) assessment methods. Briefly, leaf litter bags will be placed at 3 m intervals at each sampling location. Water samples will be collected concomitantly below the lowest leaf bag at each site on each sampling day and filtered in the lab within 24 hours. eDNA will be extracted following established laboratory protocols and quantitative PCR will be used to detect salamander DNA. Preliminary data indicates detection of Eurycea cirrigera (southern two lined salamander) in leaf litter bags in two of three sites but in all three sites using eDNA. The final results should both provide interesting insight into the relationship between traditional and novel methods of amphibian detection and useful data concerning the species present in Maywoods Environmental and Educational Laboratory.

14. Reusable Polymeric Sorbents and their Applications in Water Remediation

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Decades of use of per- and polyfluoroalkyl substances (PFAS) in a multitude of consumer and industry-based products have led to a devastating amount of soil and water contamination. The chemical and thermal stability of PFAS have proved them to be an especially daunting challenge from an environmental remediation standpoint. Presently, the only full-scale water treatment separates via sorption and uses non-selective materials such as activated carbon (AC) or mineral media which are extremely difficult and/or costly to regenerate. Developing effective and renewable remediation technologies that lead to clean and safe drinking water sources are therefore a vital part of current research efforts. Research focused on selective adsorption is becoming a more practical route for capture and removal from contaminated water systems.

This work seeks to develop and assess various polymeric and nanocomposite adsorbents that have affinity towards two of the most commonly detected PFAS, perfluorooctanoic acid (PFOA) and perfluorosulfonic acid (PFOS). Two routes of sorption were explored: (1) contaminant binding and removal via magnetic decantation of functionalized polymer composites; (2) contaminant binding through flocculation with functionalized thermo-responsive polymers. Polymers are synthesized via free radical polymerization reactions with (1) amine functionalized cationic monomers with crosslinker N,N'-methylenebisacrylamide (NMBA) (2) N-isopropylacrylamide (NIPAAm) and various cationic and/or fluorinated comonomers

In some instances, composite systems were created with the inclusion iron oxide nanoparticles during the synthesis process. Two types of binding systems and removal are examined depending on polymer structure (i.e. crosslinked or linear). Binding studies are conducted by subjecting 2.5 mg/mL of each sorbent to 500 ppb of aqueous PFAS for up to 24 h at room temperature for crosslinked systems and 1 h at 50 ºC for linear systems. Cationic crosslinked polymers showed high affinity for PFOA (>80%) and PFOS (>90%) across a range of aqueous pH (4 – 10). Linear polymers that included both cationic and fluorinated monomers showed improved flocculation and contaminant removal as compared to those systems with isolated functionality. Both routes of treatment show promising results for future application as water remediation materials.

15. Investigating Plant-Soil Processes and Nitrate Seasonality Using High Resolution Sensors and Stable Isotope Measurements

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Nitrate generated and leached from soils is a contributor to the total export of nitrogen in agricultural watersheds and can lead to water quality problems in downstream rivers, lakes and estuaries. Controls on the seasonal nitrate pattern and its delivery to water bodies has been hypothesized to be dominated by soil-plant processes in some systems, such as the Ohio River Basin. For example, a hypothesized seasonal model suggests that the dormant winter season (Dec-Mar) results in plants that are relatively inactive and allow most of the nitrate to be leached through the soil rather than assimilated via biochemical processing. A spring planting season (April-June) supplies crops with ammonium nitrate fertilizers that can runoff or follow groundwater pathways that lead to high nitrate loads. A growing-harvesting season in late summer and fall (July-Nov) results in plants utilizing nutrients for growth and retaining the nitrate resulting in low instream nitrate loads. Further, the warm temperature seasons with dry soils due to high evapotranspiration demand results in a low transport rate of water and nutrients. Despite recent hypotheses and advances in knowledge gained about the nitrogen cycle, the biogeochemical and hydrologic controls on nitrate delivery in temperate water bodies remains un-resolved and under-studied.

Our research goal is to use high-resolution nitrate sensors and discrete samples of nitrate (NO_{3-}) and its isotopic signature $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ to further test hypotheses and gain new knowledge of nitrogen seasonality in temperate river systems. To do so, we use a multi-year high resolution (15 minute) submersible ultraviolet nitrate analyzer measurements and a multi-year dataset of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ collected from agricultural basins in the inner Bluegrass region of central Kentucky USA. We carry out time series analyses and load analyses to investigate biogeochemical and hydrologic controls on nitrate transfer.

Time series analyses of nitrate sensors shows 5 mg/L N peaks in January-February and 2 mg/L N lows in July-August. Analyses of $\delta^{18}O_{NO3}$ shows a similar trend to that of nitrate concentration with peaks of 4‰ in July-August and lows of 0‰ in January-February. Time series analyses shows $\delta^{15}N_{NO3}$ peaks around 9‰ in September-October and $\delta^{15}N_{NO3}$ low periods of 6‰ in March. The nitrogen isotopic signature peaks occur when nitrate delivery to the stream is low and soils are dry, allowing the enriched denitrified nitrate to be slowly leached from soil into the watershed. Statistical analysis of seasonal trends are ongoing.

Results allow further discussion of nitrate processes in soils of watersheds. The spatial variability of soil properties produces conditions where nitrate can be at different stages of its oxidation-reduction potential and therefore differs in both the amount of available nitrate as well as its isotopic signature. In an ammonium-limited system the nitrate generated via mineralization-nitrification shows little fractionation and instead the nitrate will have a similar isotope signature towards that of the organic nitrogen source. This process is observed in the March low periods of the multi-year isotope datasets. Denitrification shows a distinct fractionation of both $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ that tends to increase the isotope signature due to preferential removal of the lighter isotope. This process is observed in the isotope peaks in the fall period. In the present agricultural soil system, we expect these peaks and low nitrate isotope results reflect a lag time in the system. For example, nitrate sensor lows and highs occur in July-August and January-February, but the corresponding shifts are not seen in isotope data until a one or two months later. We attribute the reason to the fact that nitrate generated via mineralization-nitrification in loose, aerated soils can be quickly transported to a river system and displays an immediate response in water as compared to nitrate that is tied up into tight and compact soil microsites. Soils with a low porosity creates the environmental conditions that limit oxygen and favor anaerobic microbes such as those that carry out denitrification. These microsites allow for partial nitrate removal but also makes the physical process of nitrate leaching more difficult (i.e. slower) than those sites that favor aerobic mineralized nitrate. The extended transport time of this pool of denitrified nitrate results in a lagged effect of the nitrate response in stream.

Future work includes further data analysis and a process-based numerical model to elucidate the fate and transport of nitrate in streams. To do so, we plan to expand the numerical modelling previously performed and focused on nitrate source and transfer in the basin. The model will be expanded to include stable isotope subroutines for soil nitrate $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$.

16. Development and Validation of qPCR Assays for use in eDNA Detection of *Ambystoma* Species

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In the past decade environmental DNA (eDNA) has become firmly established as an effective method for detecting the presence of organisms of research and conservation interest and promises to greatly increase the ease, efficacy, and scope of ecological studies. Salamanders of the family Ambystomatidae are large, fossorial species; adults are rarely encountered aboveground outside of their brief reproductive season. Larvae develop rapidly, in ephemeral pools or streams, often with multiple species coexisting in a single habitat. A number of Ambystomatid species are of conservation interest in various portions of their range. We developed species-specific qPCR assays for *Ambystoma barbouri*, *Ambystoma jeffersonianum*, and *Ambystoma opacum* and tested them in silico, in vitro, and in situ. Tissue tests confirm specificity of primers among these three species and *A. maculatum* as well as the frequently sympatric *Notophthalmus viridescens.* To validate assays in situ larvae surveys were conducted and water samples collected from a number of sites in central and Eastern Kentucky. Initial eDNA results indicate accurate determination of species assemblage via molecular methods. These assays provide an effective means of determining species present in particular habitats rapidly and definitively and therefore offer to increase the ease of range delineation and spawning habitat studies.

17. Is Chloride Driving Specific Conductance in Streams in the Upper Ohio River Valley?

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The salinization of freshwaters is increasingly recognized as a global problem, resulting in the degradation of freshwater ecosystem health and biodiversity. Salts and metals washed in from urbanized landscapes are a primary cause, but extraction industries, mining and agriculture, as well as failing sewage infrastructure, illicit discharges, eroding stream banks and other sources all contribute to the problem. Chloride (Cl) concentrations over 30 mg/L can negatively impact sensitive aquatic taxa, and specific conductivity (SPC) can cause impairment of aquatic biodiversity at concentrations well below 500 µS/cm. We sought to explore the relationship between Cl and SPC in streams in the Upper Ohio River Valley using a data set extending back to 2018. We used 21 sampling locations distributed throughout 4 tributaries to the Ohio River near Wheeling, WV, including 2 sampling sites on the Ohio River. We found that mean Cl at our sampling sites ranged from ~7 mg/L up to 269 mg/L, while mean SPC ranged from 302 µS/cm to 2,432 µS/cm. Correlation strength (R^2) of SPC and Cl ranged from >0.01 to 0.82 (mean = 0.32), with some of the lowest R^2 values occurring at sites with the lowest or highest SPC and Cl concentrations. Using each site's average Cl and the Cl to SPC regression equation, we estimated that on average Cl accounted for between 1 and 16% of the SPC at our sampling sites, suggesting that ions other than Cl constitute a majority of the SPC in these streams. However, across all sites, mean Cl and mean SPC were highly correlated ($R^2 = 0.79$), indicating that Cl concentration is predictive of the SPC in local streams. Overall our data indicates that 1) many tributaries are likely impaired (at least in part) to high concentrations of salts and metals, 2) tributaries to the Ohio River are often higher in Cl and SPC than the Ohio River itself, and 3) these tributaries are negatively impacting water quality in the Ohio River by increasing the concentrations of salts and metals in the Ohio River.

18. The Use of Electrical Resistivity Tomography for Delineating Ridgetop Wetland Hydrogeology in the Daniel Boone National Forest in Eastern Kentucky*

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Isolated ridgetop perched aquifer-wetland systems in the Daniel Boone National Forest are important environments that locally store groundwater at high elevation. During the winter and early spring, water is collected and stored above a thick, impermeable clay layer. In the spring and summer, these systems provide drought resilience for the upland forest ecosystems by supplying stored water to local forest vegetation, surface water pools that breed native amphibians, groundwater springs, and adjacent lowland ecosystems.

Previous work done by Eastern Kentucky University has shown general trends in the geologic stratigraphy and hydraulic conductivity of these groundwater-surface water systems. That said, the different variables that lay beneath the wetlands themselves including the shape of clay layers and underlying bedrock topography provide significant challenge for estimating the amount of groundwater that is stored, the rate it drains, and whether the water remains on the ridge or flows to lowlands. Electrical resistivity tomography (ERT) provides a low-impact instrument for imaging underlying geology, alongside the monitoring of groundwater levels and sediment coring at these sites. With ERT, we expect to be able to learn more about the hydrogeologic features/pathways that stored groundwater takes from these perched aquifer systems towards lower elevations. Our observations may have important implications for predicting how drought might affect the forests and stream environments of Eastern Kentucky and for creating accurate water budgets for these kinds of water systems.

In the summer of 2021, ERT was used at multiple ridgetop wetlands, and resulting transect models showed the shallow subsurface geometry (Figure 1). Cross-sections show that the geometry of impermeable clay layers are complex and vary widely in size. Clay layers often have a bowl-shape that captures subsurface water that forms the primary surface water feature when groundwater levels are high. Other common features found in the subsurface impermeable layer included subsurface "depressions" where the clay layer forms a bowl shape that is not always expressed in the surface topography and breaks in the clay layer. Subsurface depressions are of differing size and location in different wetlands. In some cases, this depression is upslope from the wetlands itself, which could mean that this feature acts like a water tower or a pocket of groundwater that forest vegetation may utilize. Finally, breaks in the clay layer serve as leakage points that may allow groundwater to slowly seep to lowlands, making these systems and important source of water to valley streams.

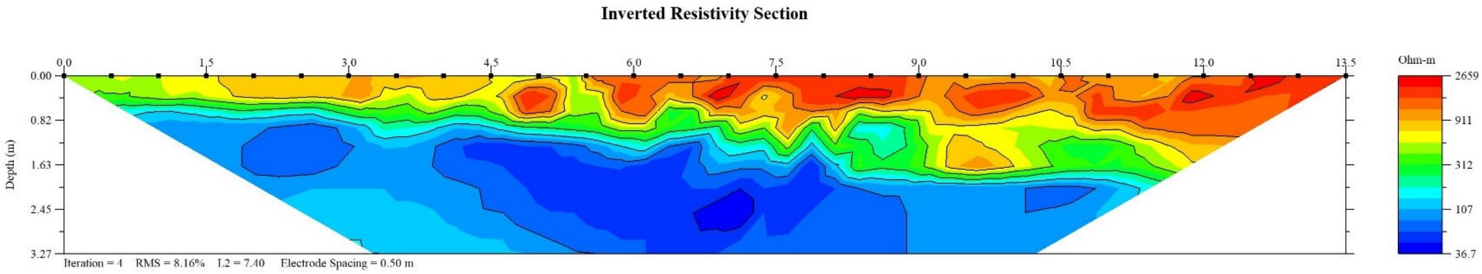

Figure 1. A transect model of a ridgetop wetland using Electrical Resistivity Tomography. The low resistivity layer (blue) represents the impermeable clay common to all of these systems. In this case the clay layer dips deeper below the land surface to create a variable aquifer geometry.

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